NASA Technical Memorandum 100703

Genesis of Atlantic Lows Experiment

NASA Electra Boundary Layer Flights Data Report

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1. EXPERIMENT BACKGROUND AND DESCRIPTION

1.1 INTRODUCTION

The Genesis of Atlantic Lows Experiment (GALE) was a multi-institutional research project designed to investigate pre-cyclogenesis conditions along the east coast of the United States. The major objective of GALE was to use the most modern and technologically advanced measurement systems to better understand the physical mechanisms controlling the development of East Coast winter storms.

One of the important components of GALE was the study of atmosphere-ocean interaction and mesoscale boundary layer processes in the pre-cyclogenesis environment. It is recognized that the fluxes of sensible and latent heat in the Marine Atmospheric Boundary Layer (MABL) play a vital yet not well understood role in the complex process of coastal storm development. The GALE field program utilized nine research aircraft to measure the important characteristics of the MABL. This document reports on the measurements of one of these aircraft, the NASA Electra which was equipped with a downward pointing lidar system used to measure the convective structure of the MABL.

The authors wish to gratefully acknowledge the imporant contributions made by the following persons: Jim Spinhime, Dave Clem, Bill Schaefer, Glenn Staley, Roger Navarro, John Cavanaugh, and Jay Smith.

1.2 EXPERIMENT DESCRIPTION

The NASA Electra aircraft, which participated in four flights during the GALE field program, carries a downward pointing lidar system used to make detailed measurements of MABL aerosol structure. The lidar system consists of a frequency doubled, 300 mJ/pulse Nd:YAG laser operating at 0.532 μm. The laser was fired at 10 shots/sec and the return data digitized every 100 nanoseconds producing a vertical resolution of 15 meters. The ground speed of the aircraft varies between 125 and 160 meters per second depending on the wind direction and magnitude, yielding a horizontal data resolution of 13-16 meters. While acquiring data, the aircraft flies at an altitude of 3 km which is well above the MABL.

The major objective of the Electra flights was to study the convective structure of the MABL during cold air outbreaks and to make high resolution measurements of the MABL height over the GALE offshore area. During cold air outbreaks the fluxes of heat and moisture are maximized and convective activity is most intense. In general, the Electra executed a flight pattern that headed offshore parallel to the mean wind for a distance of 200-300 km. Then a number of crosswind flight paths were flown as the aircraft headed back towards the coast. For each flight day, the data is broken into a number of flight segments which are normally 75-100 km long. Figures 1-8 show the flight path of the Electra on each of the experiment days as well as each individual flight segment. The flight segment number is displayed at the beginning of each flight track. The Electra participated in four missions flying coordinated flight paths with other GALE research aircraft. The data from the other aircraft will undoubtedly prove valuable for the future interpretation of the lidar data.

1.3 THE FLIGHTS

The NASA Electra participated in four flights during the GALE field project which ran from January 15 through March 15, 1986. Table 1 shows the date of each flight, the intensive operation period (IOP) number in which it occurred, a brief description of weather encountered, and the number of data segments acquired for each day. The first flight occurred during IOP number 1 on January 28, 1986. This day was characterized by a very strong cold air outbreak which produced cloud streets and Benard-type convective cells over the ocean. Partly cloudy conditions existed from about 5-10 km off the coast which gradually increased to solid cloud cover at about 100 km from shore. There were a total of five flight segments flown on this day with most of the data taken over areas with 80-100% cloud cover.

The second flight was flown on January 30, 1986, and occurred during the end of a cold air outbreak. The extremely cold air that had moved off the coast on January 28 had modified somewhat but was still well entrenched in the GALE experiment area. An abundance of clear to partly cloudy data was acquired on this day with the Electra flying 21 flight segments beginning just south of Cape Hatteras and ending off the coast of South Carolina. One of the flight segments (5) was flown in coordination with the NOAA P-3 aircraft.

Flight number 3 occurred on February 12, 1986, during IOP number 5. A weak low pressure system had formed near Cape Hatteras on February 11 producing precipitation throughout the GALE area. On the 12th, the cyclone had moved out to sea and cold air associated with a large anticyclone located over the central U.S. began to move into the region. There was a limited amount of data acquired on this day because of an electrical problem in the power supply of the lidar system. A total of three flight segments were obtained, consisting of clear to partly cloudy data, before system failure.

The fourth and final flight was conducted on March 2, 1986. This flight occurred at the end of IOP 11 and was characterized as a cold air outbreak case. On the previous day, cyclogenesis had occurred over the open ocean east of Cape Hatteras and moved rapidly northeastward. By the next day (March 2) cold air was moving offshore on brisk northwesterly winds. The

flight lasted about 7 hours and 19 segments of high quality data were obtained under clear to partly cloudy conditions. Two of the flight segments (10 and 12) were extremely short and will not be presented here.

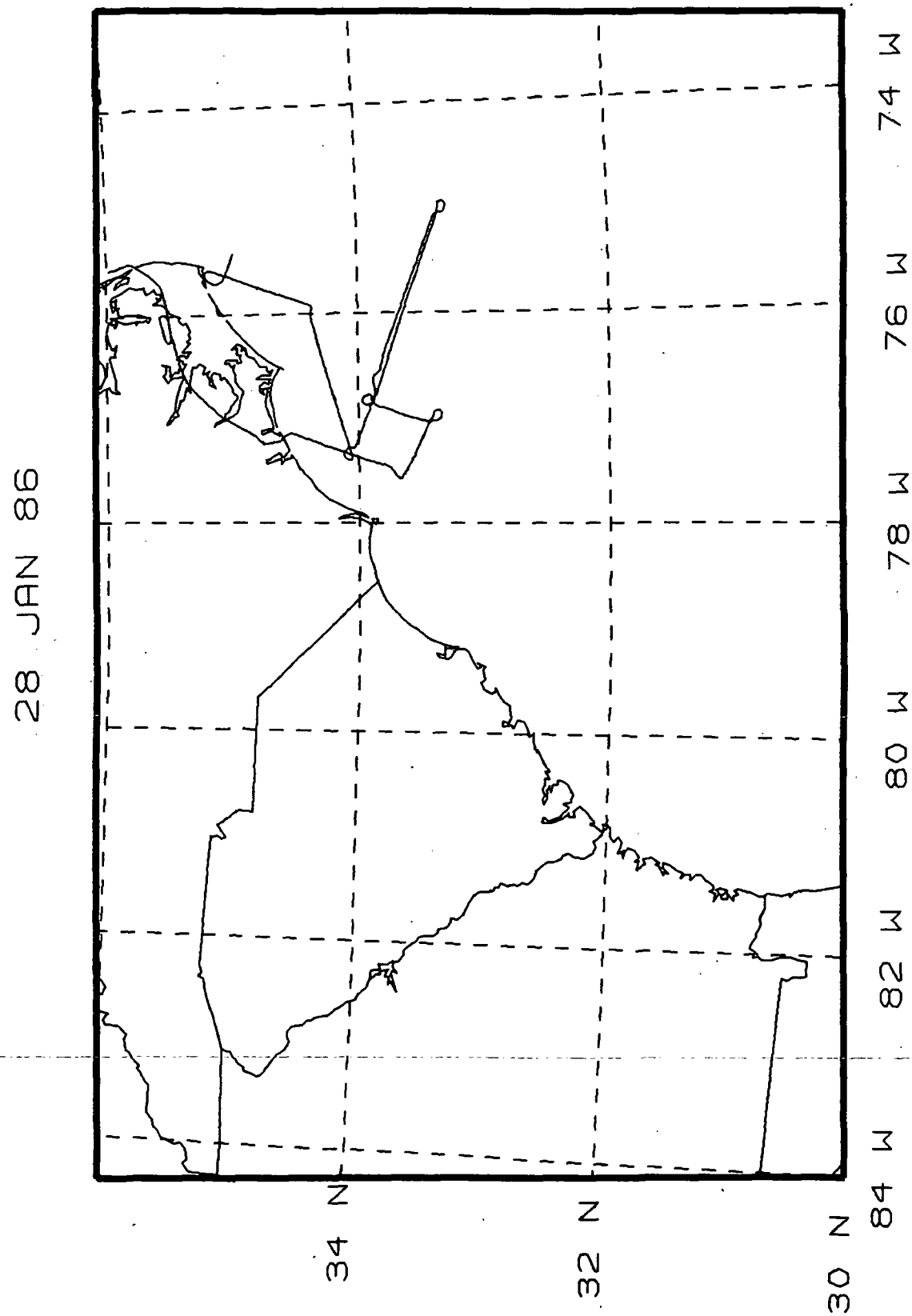


Figure 1. Map of the aircraft flight track while in the experiment area for Flight 1, 28-Jan-86.

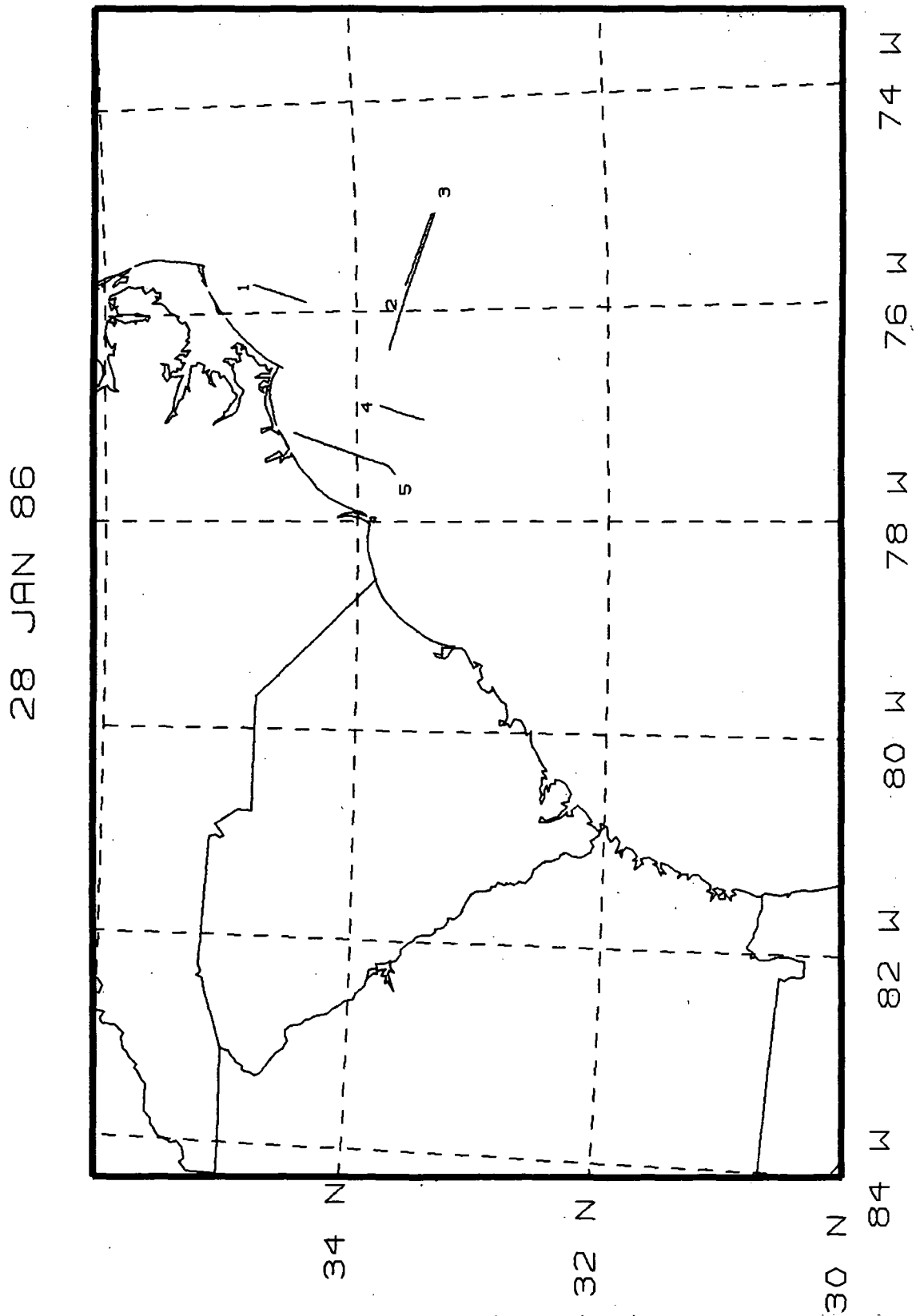


Figure 2. Map of individual flight segments 1-5 for Flight 1, 28-Jan-86.

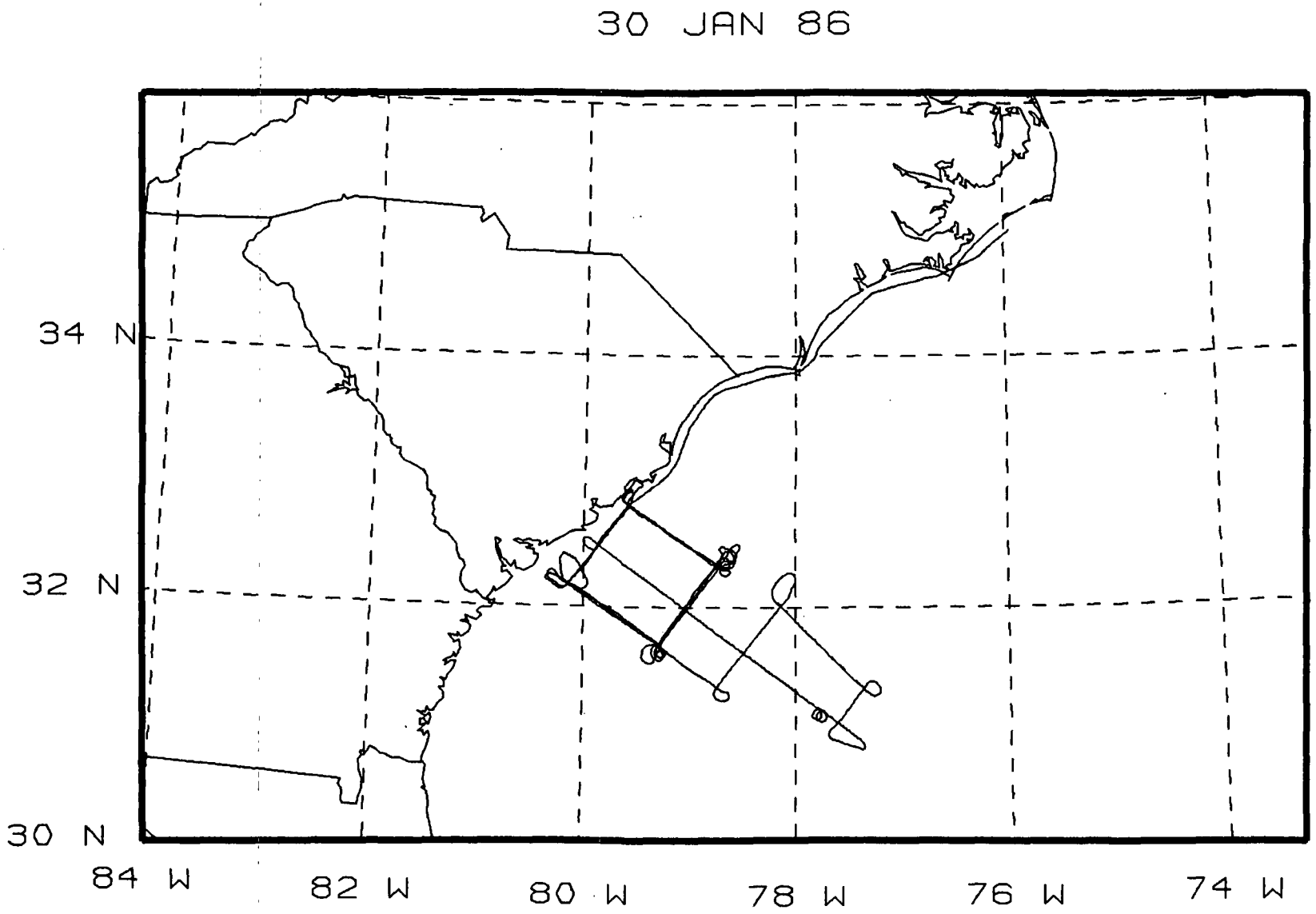


Figure 3. Map of the aircraft flight track while in the experiment area for Flight 2, 30-Jan-86.

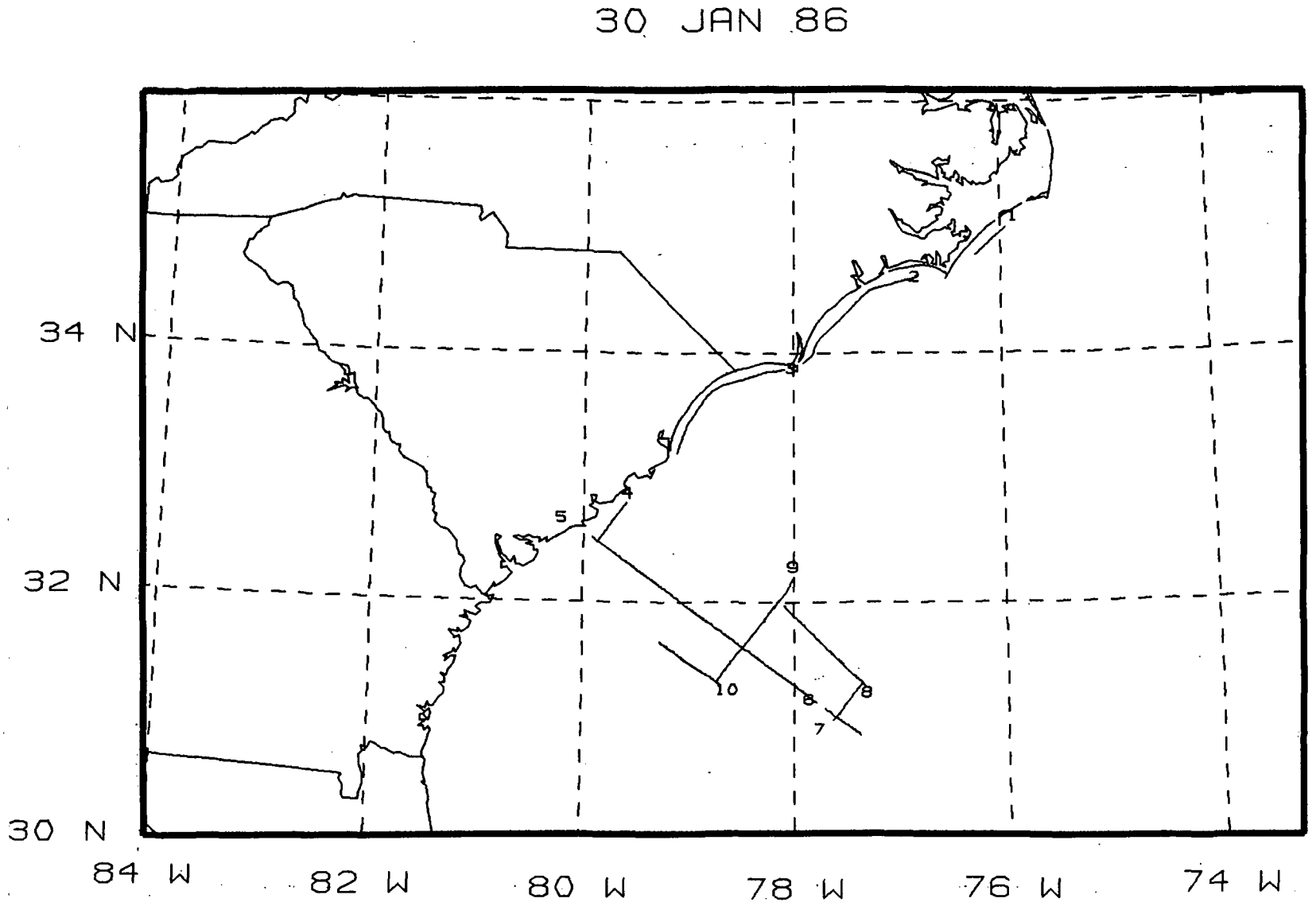
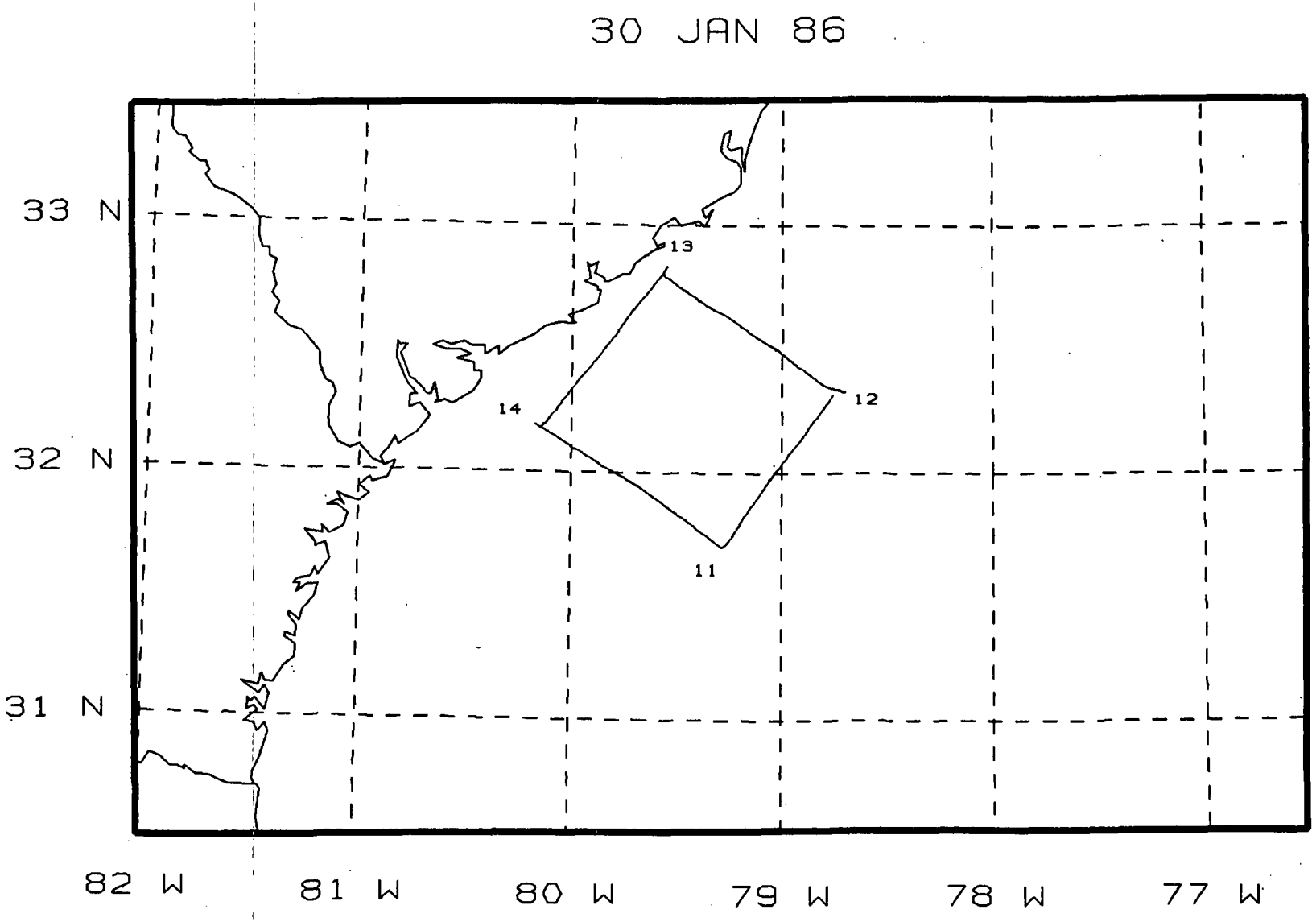


Figure 4a. Map of flight segments 1-10 for Flight 2, 30-Jan-86.



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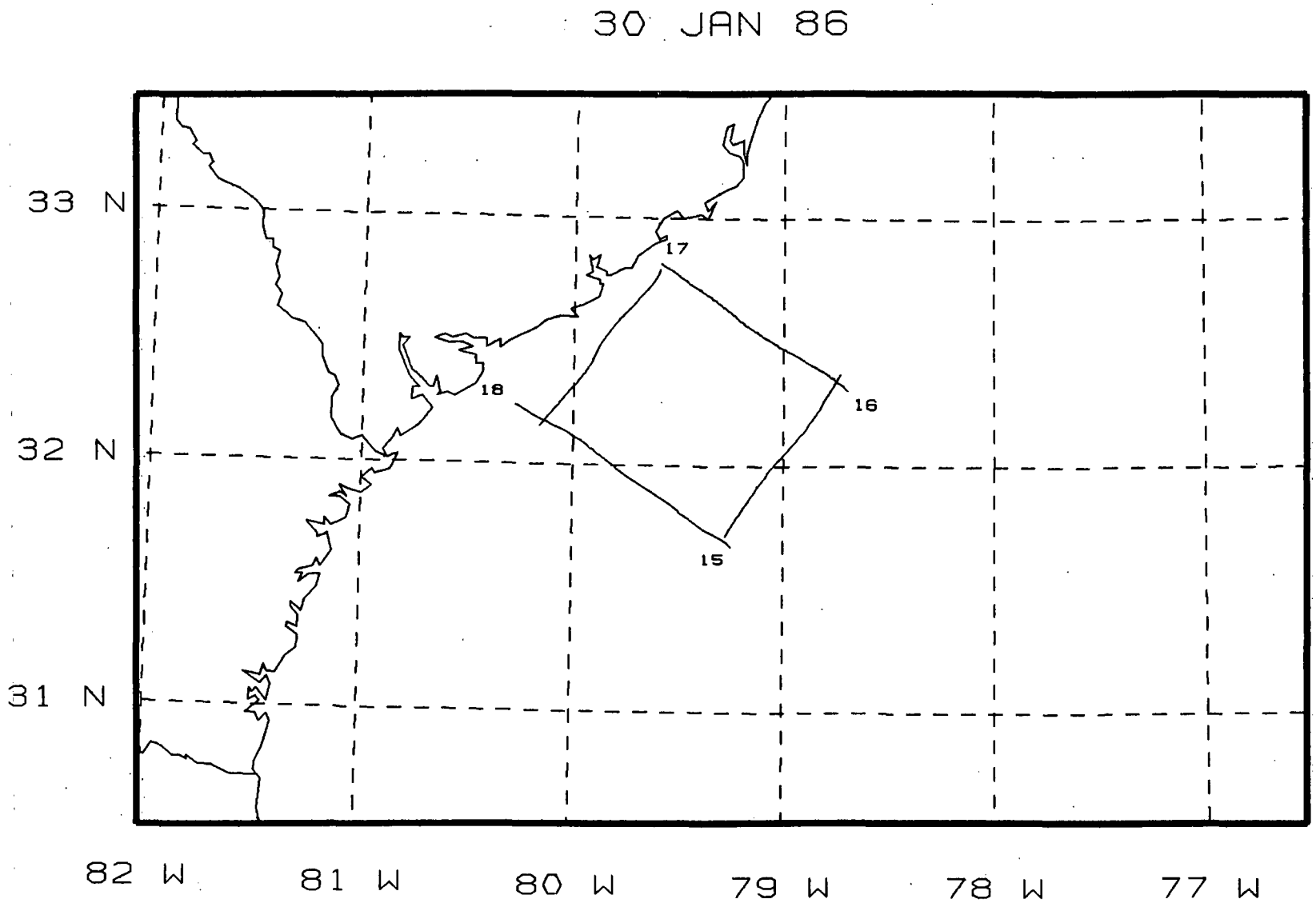


Figure 4c. Map of flight segments 15-18 for Flight 2, 30-Jan-86.

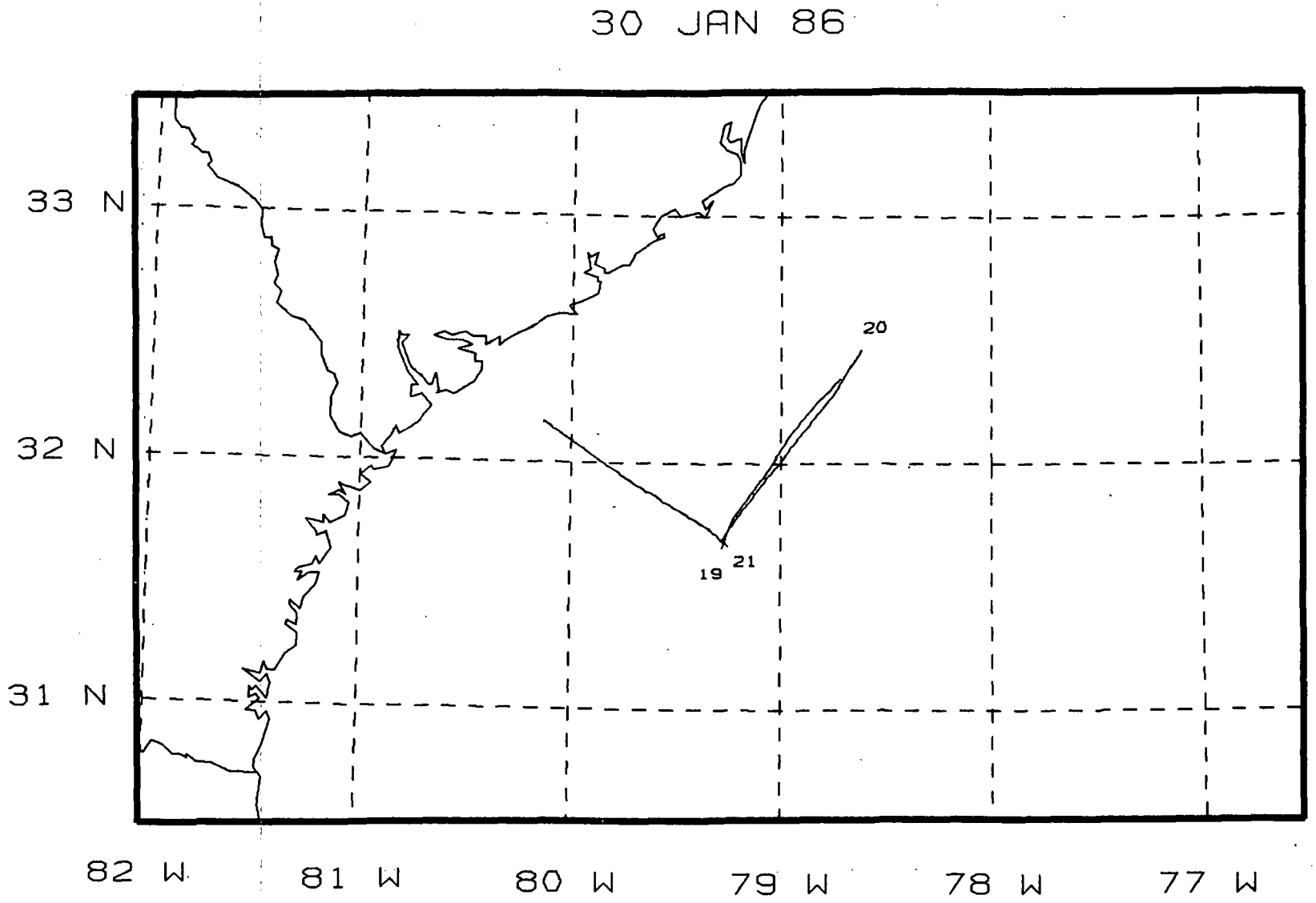


Figure 4d. Map of flight segments 19-21 for Flight 2, 30-Jan-86.

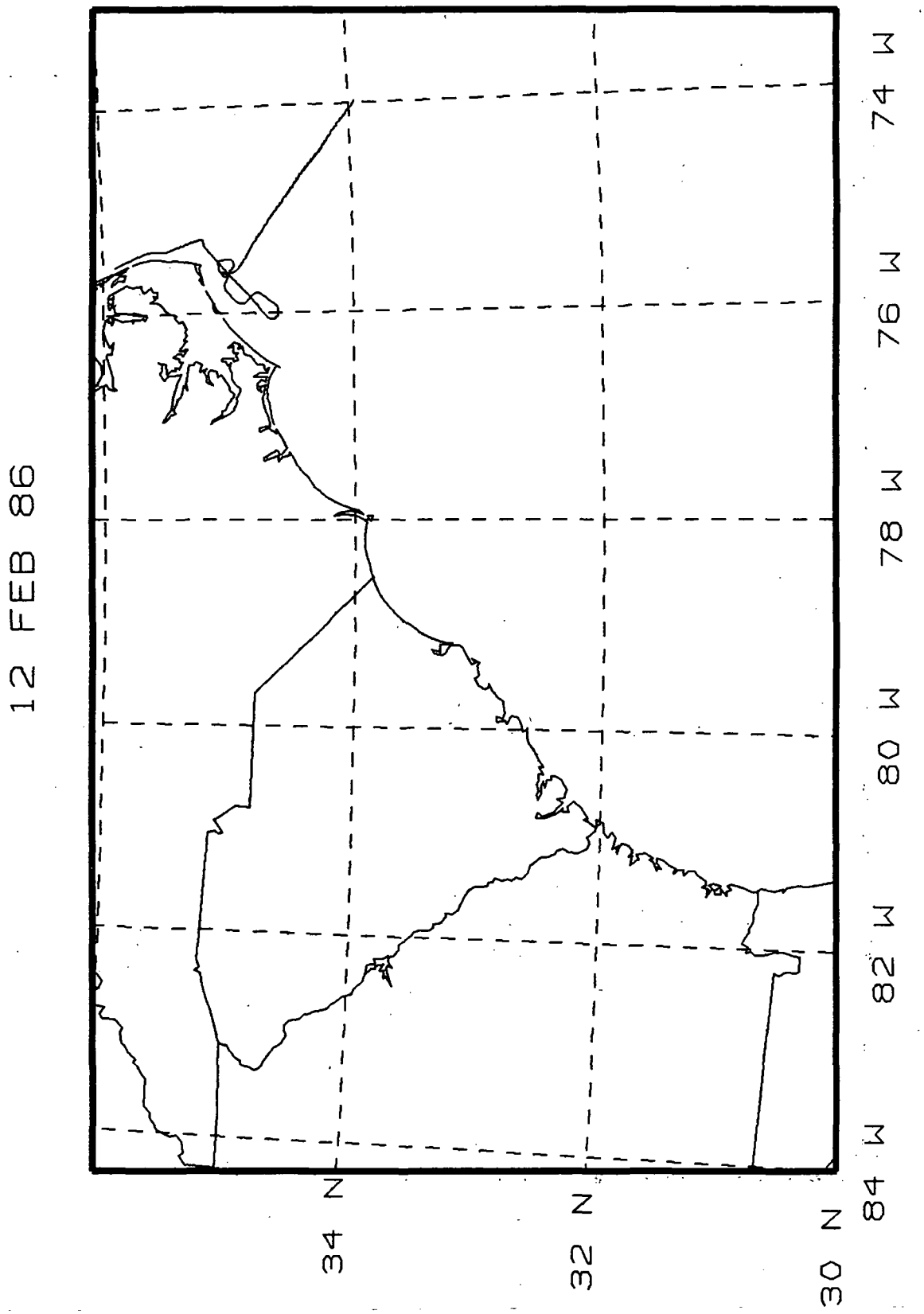


Figure 5. Map of the aircraft flight track while in the experiment area for Flight 3, 12-Feb-86.

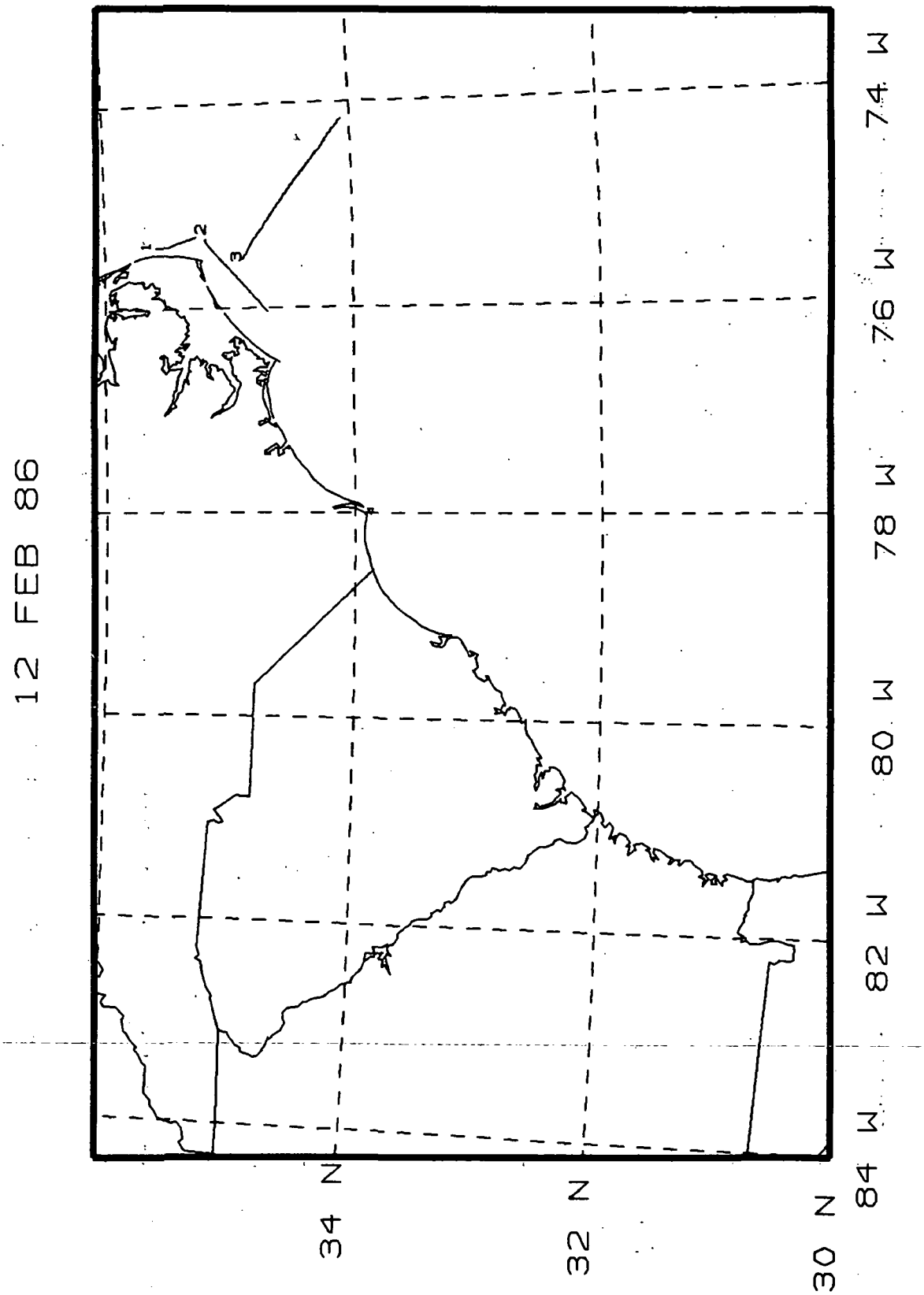
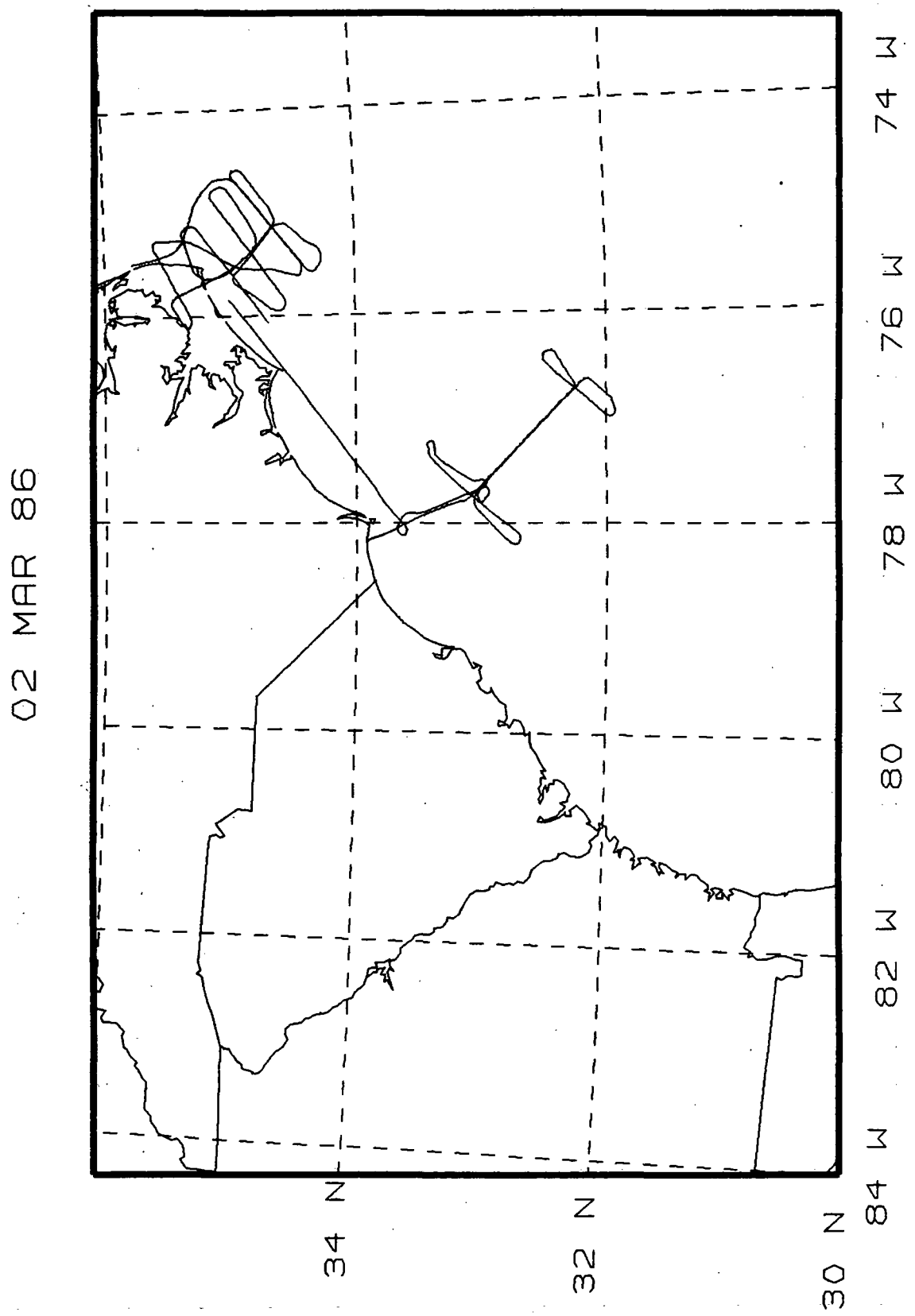


Figure 6. Map of individual flight segments for Flight 3, 12-Feb-86.



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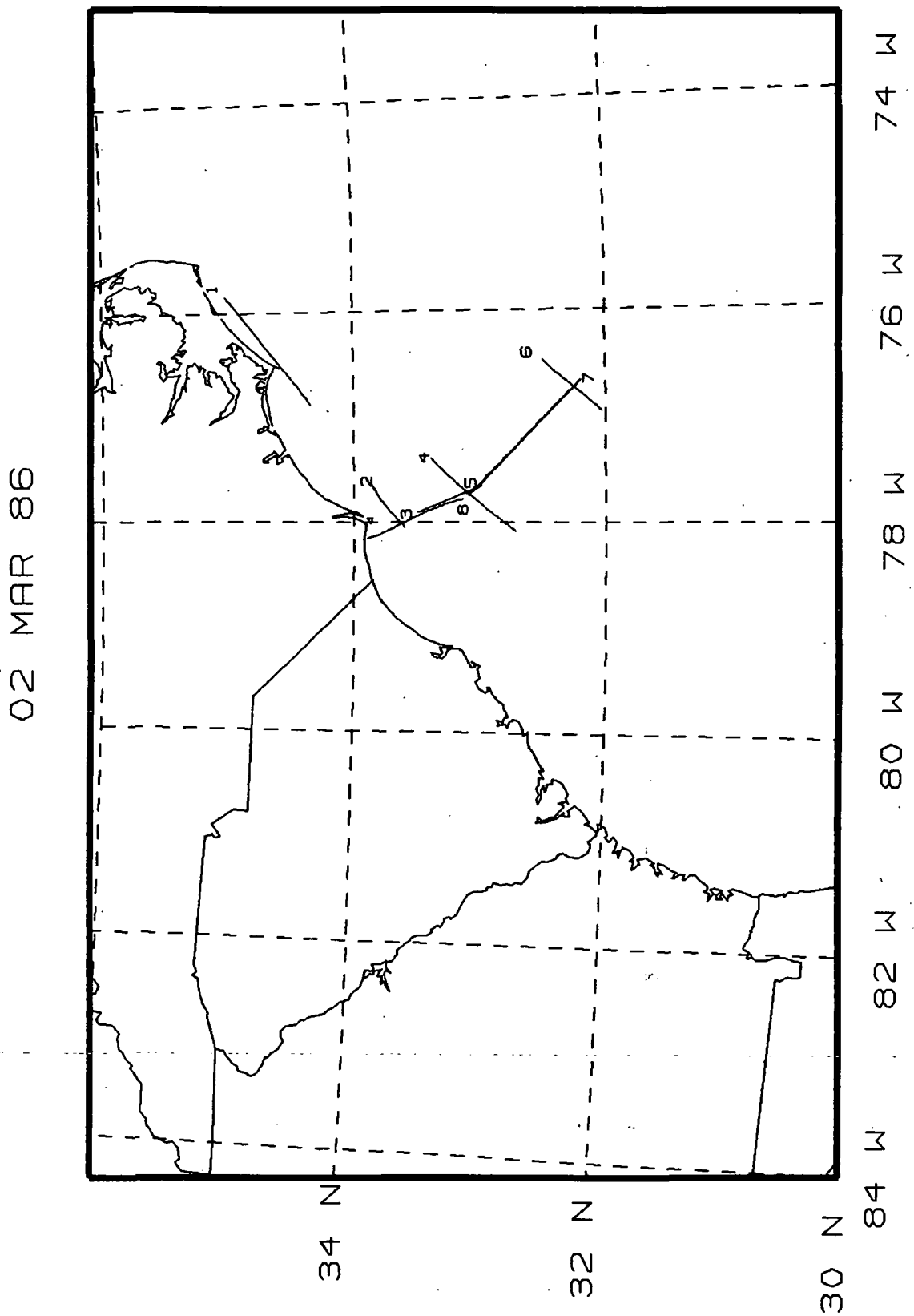

Figure 8a. Map of flight segments 1-8 for Flight 4, 02-Mar-86.

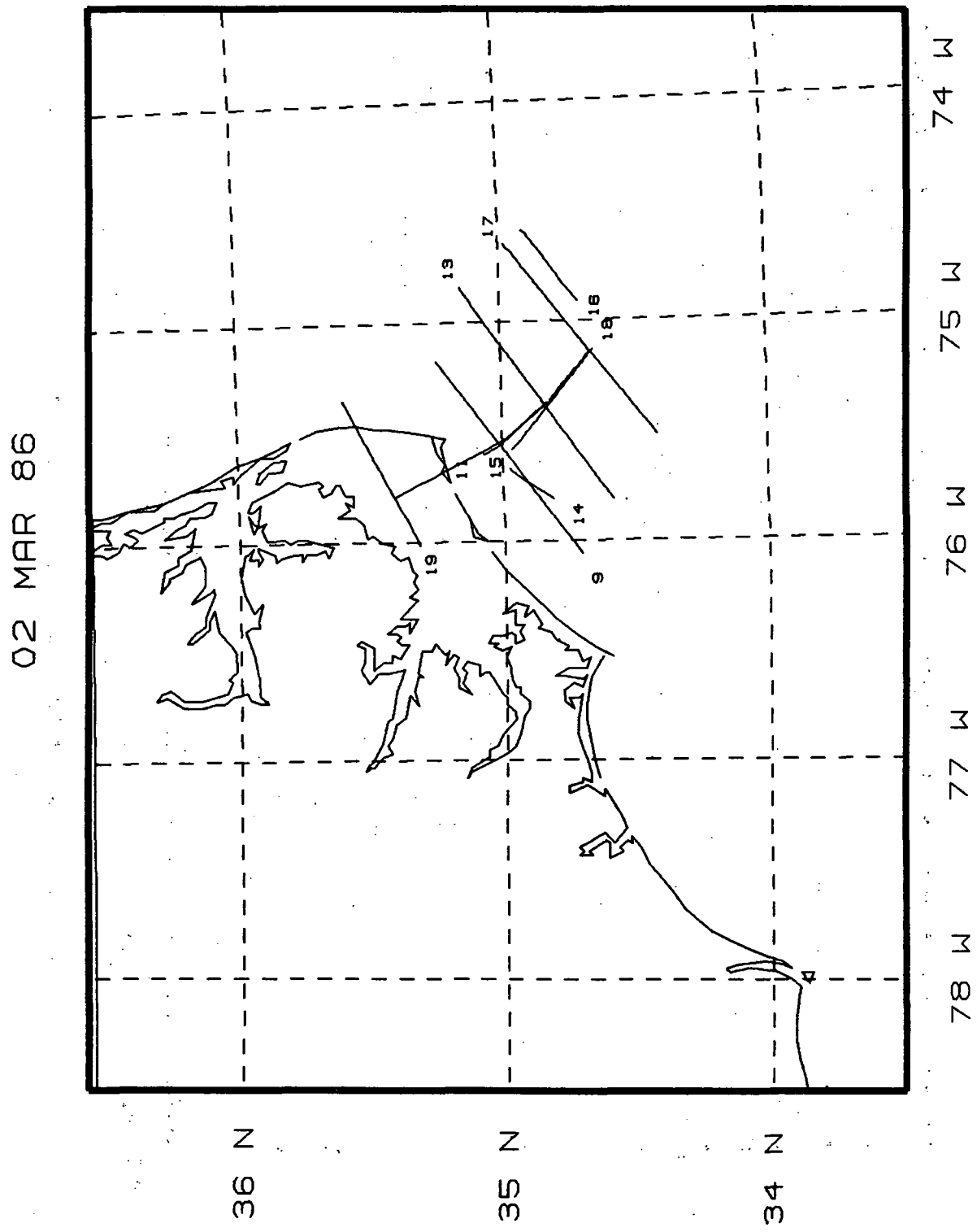

Figure 8b. Map of flight segments 9-19 for Flight 4, 02-Mar-86.

2. DATA ANALYSIS TECHNIQUES

2.1 PRELIMINARY DATA ANALYSIS

The lidar data system is controlled by a PDP 11/23 processor which fires the laser and stores the return data on magnetic tape. The data is later transferred to an IBM 3081 mainframe computer and processed into files which contain latitude, longitude and time information for each lidar record. Since no accurate altitude information is available, the lidar data itself is used to determine the plane height. This is easily accomplished except in regions of cloud cover where the laser pulse is attenuated before reaching the ground. In these areas, the plane height is interpolated between the last ground return and the next available one. In partly cloudy areas this does not present a problem, but in regions of extensive cloud cover, the uncertainty in the aircraft height could result in substantial error in the MABL height retrieval. The aircraft usually maintains a fairly level flight path while the lidar system is operating and the error introduced by interpolation of plane height probably does not exceed 75 meters even in areas of 80-90% cloud cover.

After the aircraft altitude has been determined, the background is computed by averaging 50 data points well after the ground return (during this time the telescope is collecting only ambient light). The background value is subtracted from the data which is then range square corrected and normalized by the energy of the laser pulse. The data is then organized into separate files for each flight segment.

2.2 MABL HEIGHT RETRIEVAL

The ability of the lidar to detect aerosol structures within the atmosphere has been widely demonstrated in the literature. Moreover, many investigators have shown that lidar is uniquely suited for the remote detection of atmospheric boundary layers (Kaimal *et al.*, Kunkel *et al.*, and Melfi *et al.*) Aerosols (dust, smoke, salt nuclei, etc.) accumulate in the boundary layer and are carried aloft by convective motions. The convective plumes (and aerosols) can travel only as high as the base of the capping inversion. The air at the inversion base is cool and moist and contains a relatively high concentration of aerosols. The air above the inversion is dry and contains considerably less aerosol per unit volume. The resulting gradient of aerosol concentration (as well as moisture) at the boundary layer interface is what enables an optical remote sensing system such as lidar to detect the top of atmospheric boundary layers. Because it relies on aerosol and moisture gradients, the lidar technique will not work well in very dry and/or aerosol-free boundary layers. Fortunately, these conditions are rare.

The objective of this stage of data analysis is to retrieve the height of the MABL from each individual lidar return, producing a high resolution data set of the top of the MABL. Much time and effort were spent in developing and optimizing an algorithm that was suitable for the varying conditions encountered during the four GALE flights. In particular, multiple stratified aerosol layers were frequently seen in the free troposphere which were nonconvective in nature. The layers, sometimes as many as two or three, are probably aerosols of continental origin and must be excluded from the convective layer height retrieval process. The detailed discussion of the height retrieval algorithm that follows will clarify how this is accomplished.

The technique used to retrieve the MABL heights consists of essentially two parts. The first step is to average a number (usually 20-50) of lidar returns so that the signal-to-noise ratio is increased. From this averaged profile, a mean MABL height is computed as described below. The next step involves using the mean MABL height as a guide for the height retrieval from each individual lidar profile. This process is repeated for successive 20-50 shot segments until all data for the flight line have been analyzed.

The mean MABL height for any segment is determined by computing a 75 to 150 meter (5-10 data points) running vertical average of the mean lidar profile starting from 100 meters above the ground and continuing up to a maximum predefined height. This is called the smoothed signal. The running vertical average is intended to further reduce the noise in the lidar signal. The maximum signal level as well as the height of its occurrence is then computed for the smoothed signal profile. The smoothed signal is then examined from the level of the maximum signal upwards for the location of a rapid decrease of the return signal with height (gradient of aerosol backscatter intensity). By searching upward in height, the algorithm will detect the lowest layer if multiple layers are present. The search begins at the height of maximum signal since the top of the boundary layer is assumed to always occur above the height of maximum signal return. Once a sizeable gradient has been found, the average of the four data points used in computing the gradient is taken. If this value is less than 70% of the maximum smoothed signal strength, then the MABL top has been found. If, however, the value is greater than 70% of the maximum smoothed signal level, the search continues upward along the smoothed profile for the occurrence of another gradient. The 70% of maximum signal criteria is used because sometimes gradients exist within the MABL which look like the top but are in fact simply vertical gradients within the boundary layer. Through a process of trial and error, it was found that this type of restriction helps to eliminate such spurious MABL height retrievals.

After the mean MABL height has been computed, each individual shot from the 20 or 30 shot group is examined in a similar manner for the MABL height with the following exceptions. The large gradient of aerosol backscatter characteristic of the MABL top is searched for in only a small window around the mean MABL height for that segment. The window is normally 300-400 meters wide and centered on the mean height. By searching for the top in only a small region, the number of extraneous heights which might otherwise be produced by the algorithm is reduced. Once a height has been found there are a number of checks performed to ascertain if the height is valid. First, if the maximum signal strength of a given lidar shot is below a certain value, the MABL height is not determined. This was done because in areas of extremely low backscatter, a MABL height cannot be meaningfully defined even though the algorithm may select a height. The height is also compared against a local height value (average of last five shots) and if it differs by more than 200 meters, it is not determined.

2.3 MABL HEIGHT RETRIEVAL ACCURACY

A few words regarding the accuracy of the lidar MABL height retrieval technique are in order. The depth of the boundary layer is generally defined as the height of the base of the capping temperature inversion. Other characteristics such as the height of a large decrease in relative humidity can also be used to define the MABL top. In addition, there is often (but not always) a wind shift at the top of the boundary layer. However, even with conventional data such as these, it is not straightforward to pinpoint the exact top of the boundary layer. This is mainly because the boundary layer top is not a single point but more of a transition region that varies in thickness depending on the strength of the overlying inversion. The same problem exists when inferring the MABL top from lidar data. The lidar data show quite well the location of the transition region, but the determination of the exact top of the MABL is somewhat arbitrary. Some investigators have used the height of maximum backscatter to denote boundary layer top, Kaimal *et al.* (1982), while others use the maximum backscatter gradient approach (Sasano *et al.* 1982, Goroch *et al.* 1984). The technique used here is a modified version of the maximum backscatter gradient method, as this method was tried but found to be excessively noisy under typical conditions. Any method, however, will tend to give poor results as the level of aerosol backscatter decreases and appreciable backscatter gradients disappear. Other investigators have shown that lidar-derived boundary layer heights agree well with conventional measurements (see Kaimal *et al.* 1982 or Melfi *et al.* 1985). The MABL height profiles presented in Section 3 are felt to be to within plus or minus 45 meters. The major errors involve the precise determination of the ground from the lidar return ($\pm$15 meters) and the problem of selecting one point along a gradient (which is normally about 100 meters wide in the vertical) to represent the MABL top.

Another problem which should be noted is that in regions within 10-20 km of the coast, internal boundary layers are sometimes present. Such layers typically develop a few km off the coast and grow up into the overlying aerosol layer within 20 km of shore. Internal boundary layers are very difficult to detect with the airborne lidar system because the aerosol gradients between them and the overlying layer are extremely small. The layers can be detected if enough lidar shots are averaged together (40-50), but on an individual shot basis this is probably impossible to do. Thus, for the flight segments which begin or end at the coast, the heights shown in Section 3 do not include internal boundary layers if they do exist. Image analysis has indicated that for most flight days, such internal boundary layers are indeed present.

TABLE 1
NASA ELECTRA BOUNDARY LAYER FLIGHTS

Date	IOP #	Weather	# Flight Segments
28-Jan-86	2	Strong CAO partly-mostly cloudy	5
30-Jan-86	2+ 1 day	CAO clear - partly cloudy	21
12-Feb-86	5	CAO clear-partly cloudy	3
2-Mar-86	11	CAO clear-partly cloudy	19

3. MABL HEIGHTS

Figures 9-12 show the results of the height retrieval process for the four Electra flights of the GALE experiment. A seven point normal filter has been applied to the data shown in the figures. Each flight segment is displayed in 24 km segments so that the fine-scale detail in the MABL height can be seen. Displaying longer segments of data in one plot tends to obscure the small fluctuations of the MABL top. Data points that could not be resolved by the algorithm are shown as points plotted at the 200 meter level. The lidar system can easily detect the presence of clouds by the absence of a ground return. In Figures 9-12, the points plotted at the 2800 meter level indicate the occurrence of clouds.

Tables 2-5 show the beginning and ending time, latitude, longitude, percent cloud cover, percent bad or unretrievable data and the average MABL height for each flight segment. From the tables it can be seen that the data from March 2, 1986 is of highest quality with almost all segments showing less than 1 percent unretrievable data. Most difficulty was encountered with the February 12, 1986 data set which has an average of 28 percent bad data points. This was mainly due to problems with the lidar system power supply. The data from January 28 and 30, 1986 is of good quality with many flight segments having less than 1 percent of unretrievable data.

TABLE 2
FLIGHT 1, 1/28/86

Flight Segment	Begin Time	End Time	Begin Lat/Lon	End Lat/Lon
1	16:31:29	16:37:50	34.83, 75.72	34.40, 75.91
2	17:16:00	17:23:10	33.60, 75.77	33.38, 75.07
3	17:27:00	17:44:00	33.36, 75.07	33.74, 76.37
4	17:54:16	17:58:36	33.81, 76.90	33.46, 77.03
5	18:13:25	18:20:46	33.69, 77.56	34.51, 77.15

Flight Segment	% Clouds	% Bad Shot	Avg MABL Height (km)
1	28.0	6.6	0.675
2	96.0	1.3	1.985
3	96.3	3.6	1.677
4	77.6	0.0	0.998
5	0.0	3.0	0.851

TABLE 3
FLIGHT 2, 1/30/86

Flight Segment	Begin Time	End Time	Begin Lat/Lon	End Lat/Lon
1	15:22:30	15:28:04	34.99, 75.95	34.73. 76.37
2	15:34:15	15:49:36	34.59, 76.88	33.91, 77.91
3	15:51:46	16:07:58	33.86, 78.09	33.19, 79.12
4	16:15:42	16:20:55	32.80, 79.60	32.48, 79.87
5	16:24:18	16:49:59	32.53, 79.93	31.19, 77.79
6	16:57:30	17:01:50	31.16, 77.72	30.93, 77.38
7	17:08:20	17:13:19	31.05, 77.64	31.35, 77.36
8	17:17:37	17:32:15	31.33, 77.34	31.98, 78.10
9	17:39:00	17:53:59	32.20, 78.00	31.36, 78.74
10	17:58:30	18:07:28	31.34, 78.72	31.68, 79.28
11	18:13:50	18:24:00	31.70, 79.28	32.33, 78.75
12	18:26:15	18:39:00	32.33, 78.70	32.81, 79.58
13	18:45:00	18:55:28	32.84, 79.55	32.18, 80.14
14	19:11:15	19:21:40	32.19, 80.18	31.69, 79.28
15	19:24:00	19:33:25	31.71, 79.28	32.38, 78.73
16	19:41:30	19:54:12	32.31, 78.69	32.82, 79.60
17	19:58:00	20:07:49	32.80, 79.59	32.15, 80.16
18	20:12:15	20:23:08	32.24, 80.28	31.67, 79.25
19	20:25:40	20:35:12	31.65, 79.28	32.35, 78.71
20	20:47:20	20:58:45	32.47, 78.61	31.68, 79.29
21	21:01:20	21:13:01	31.66, 79.25	32.17, 80.14

Flight Segment	% Clouds	% Bad Shot	Avg MABL Height (km)
1	0.0	0.8	0.711
2	0.0	5.4	0.956
3	0.0	5.0	1.030
4	0.0	0.7	0.646
5	24.4	2.6	1.071
6	13.6	2.4	1.256
7	38.1	8.4	1.343
8	35.8	3.2	1.123
9	41.4	3.5	1.064
10	30.7	0.8	1.073
11	16.4	0.7	0.928
12	0.1	0.9	0.796
13	0.0	0.7	0.834
14	2.2	0.8	0.840
15	5.5	1.0	0.860
16	1.0	1.3	0.802
17	0.2	2.1	0.927
18	2.9	0.7	0.816
19	4.7	0.9	0.856
20	5.3	0.4	0.856
21	0.6	0.5	0.750

TABLE 4
FLIGHT 3, 2/12/86

Flight Segment	Begin Time	End Time	Begin Lat/Lon	End Lat/Lon
1	16:19:00	16:23:58	35.60, 75.40	35.27,75.30
2	16:28:35	16:39:09	35.19, 75.33	34.70,76.03
3	17:00:30	17:18:29	34.89, 75.52	34.07,74.17

Flight Segment	% Clouds	% Bad Shots	Avg MABL Height (km)
1	14.2	19.0	0.796
2	19.0	48.6	0.817
3	70.6	15.8	1.353

TABLE 5
FLIGHT 4, 3/2/86

Flight Segment	Begin Time	End Time	Begin Lat/Lon	End Lat/Lon
1	12:32:49	12:48:12	35.03, 75.84	34.26, 77.04
2	12:53:01	13:01:23	34.08, 77.31	33.64, 78.06
3	13:06:42	13:14:26	33.51, 77.91	33.00, 77.66
4	13:27:18	13:40:11	33.40, 77.39	32.75, 78.07
5	13:56:00	14:10:18	33.01, 77.67	32.27, 76.74
6	14:17:23	14:26:36	32.50, 76.48	32.03, 76.95
7	14:34:14	14:52:40	32.20, 76.67	33.09, 77.75
8	14:53:23	15:05:12	33.16, 77.77	33.85, 78.08
9	17:18:53	17:31:17	34.57, 76.33	35.22, 75.22
11	17:42:30	17:46:59	35.07, 75.66	34.82, 75.42
13	17:57:19	18:13:29	35.13, 74.87	34.57, 75.85
14	18:19:04	18:21:45	34.79, 75.86	34.95, 75.72
15	18:22:49	18:29:22	34.96, 75.63	34.64, 75.17
16	18:31:55	18:36:16	34.67, 74.96	34.88, 74.63
17	18:37:55	18:53:10	34.96, 74.67	34.40, 75.56
18	19:03:27	19:19:29	34.63, 75.15	35.39, 75.82
19	19:27:00	19:37:01	35.29, 76.07	35.58, 75.39

Flight Segment	% Clouds	% Bad Shot	Avg MABL Height (km)
1	0.0	0.3	0.539
2	0.0	1.2	0.459
3	0.0	0.4	0.568
4	0.7	0.0	0.779
5	27.7	0.0	1.695
6	96.3	0.1	2.435
7	31.1	0.0	1.510
8	0.1	0.0	0.464
9	0.0	0.6	0.589
11	0.0	0.0	0.555
13	0.0	0.0	0.723
14	0.0	0.1	0.634
15	0.0	0.0	0.671
16	0.0	0.2	0.825
17	0.7	0.0	0.893
18	1.1	8.7	0.906
19	0.0	2.0	1.166

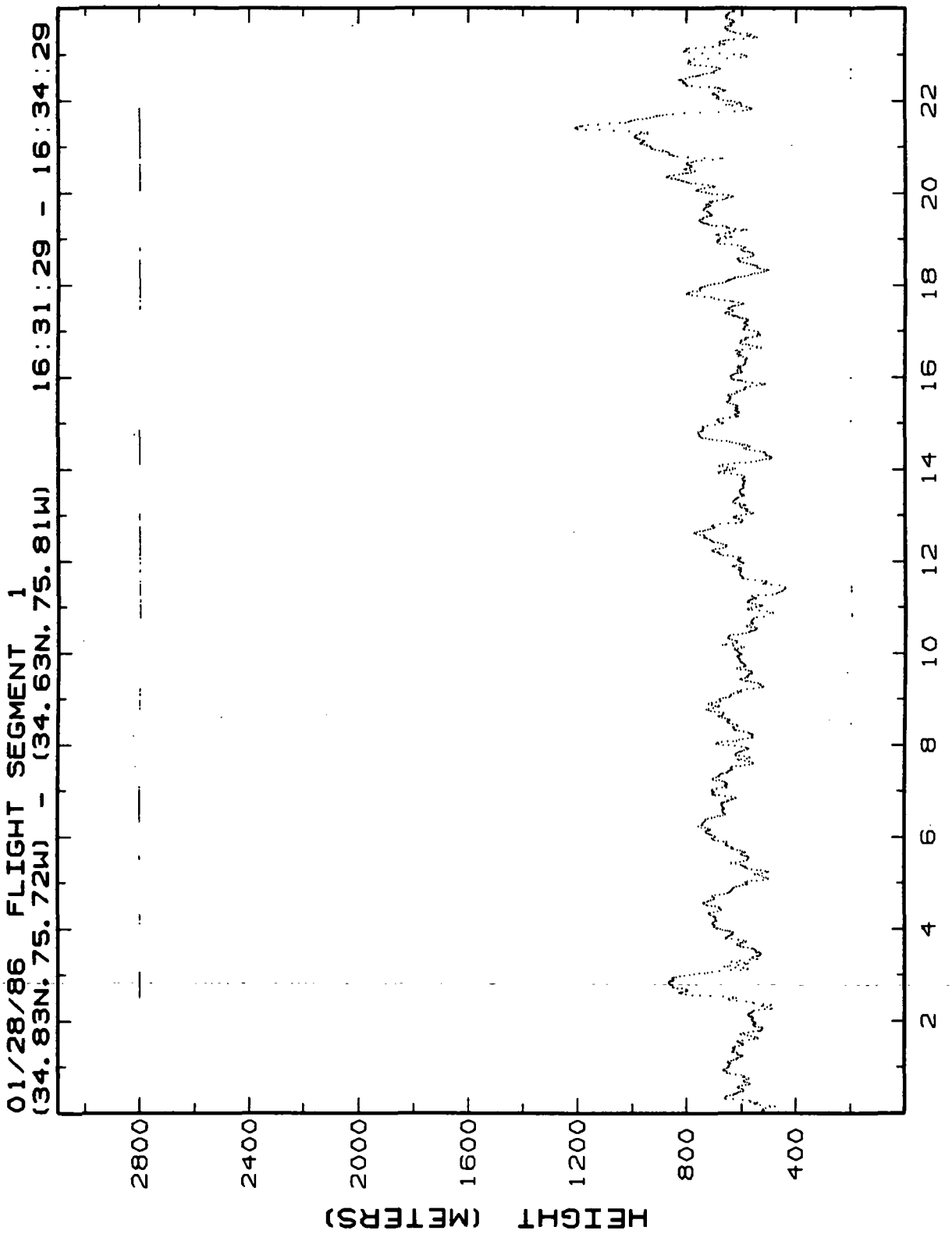

Figure 9.1a. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 1, 0-24 km.

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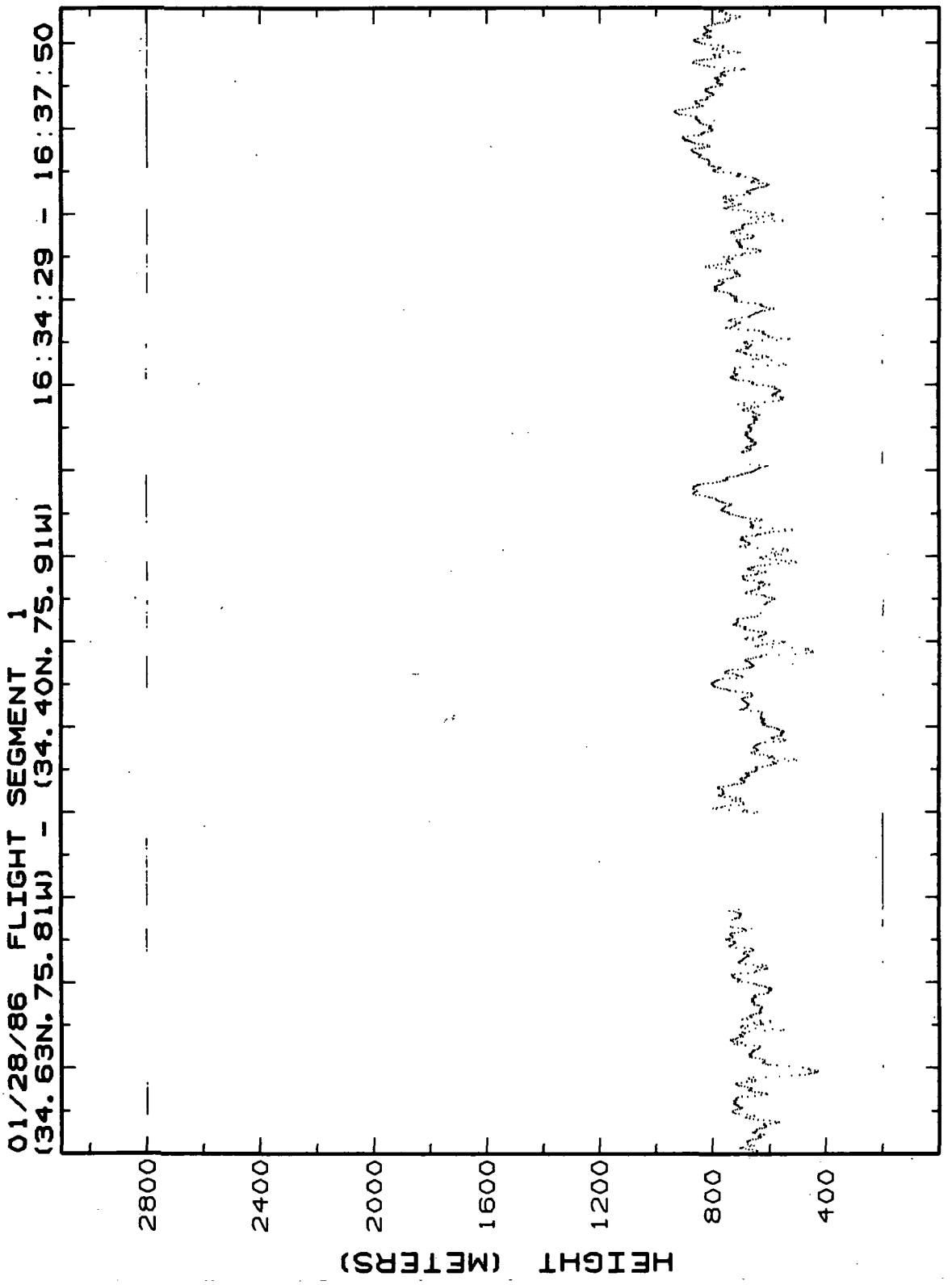

Figure 9.1b. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 1, 24-48 km.

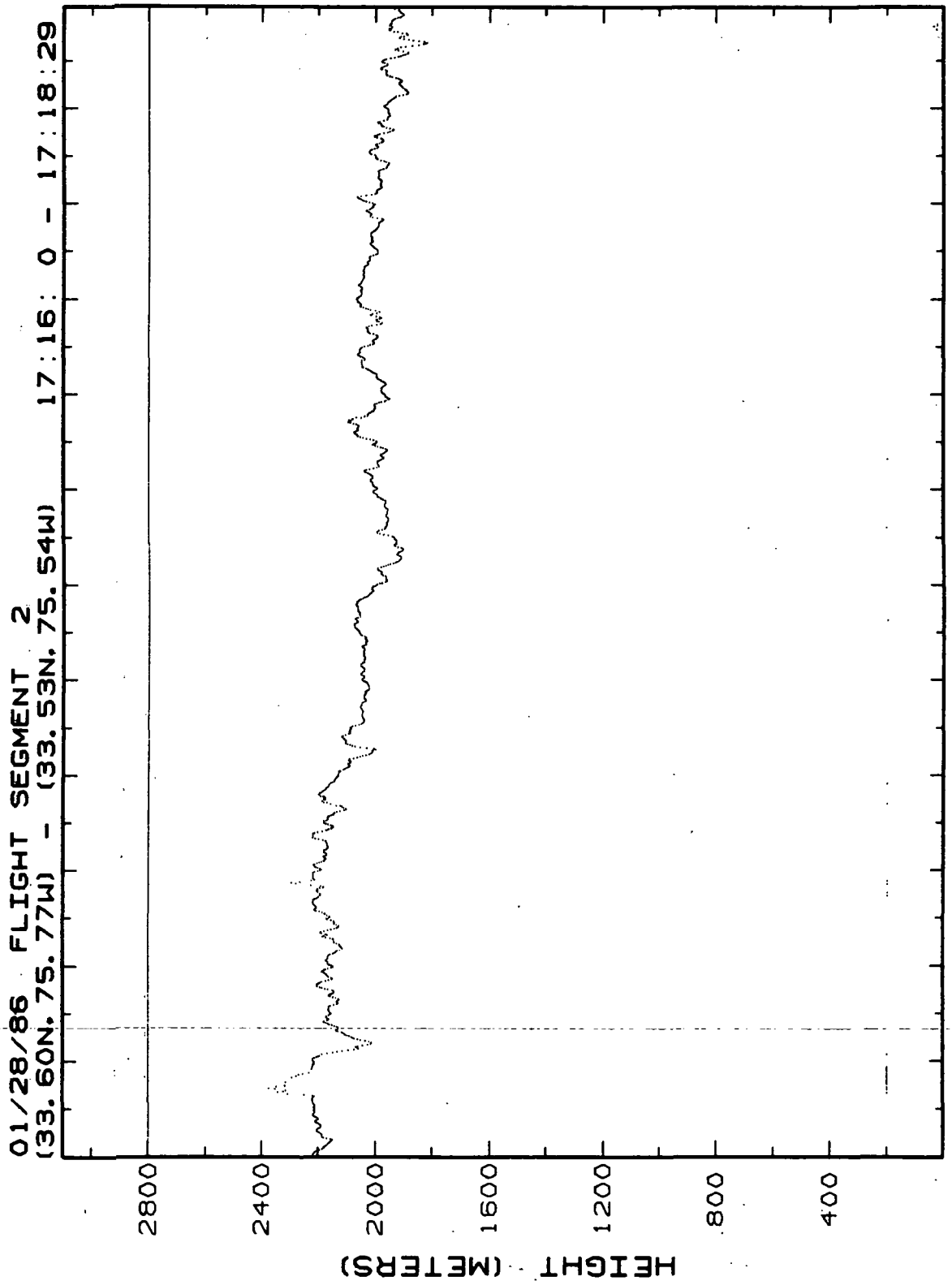

Figure 9.2a. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 2, 0-24 km.

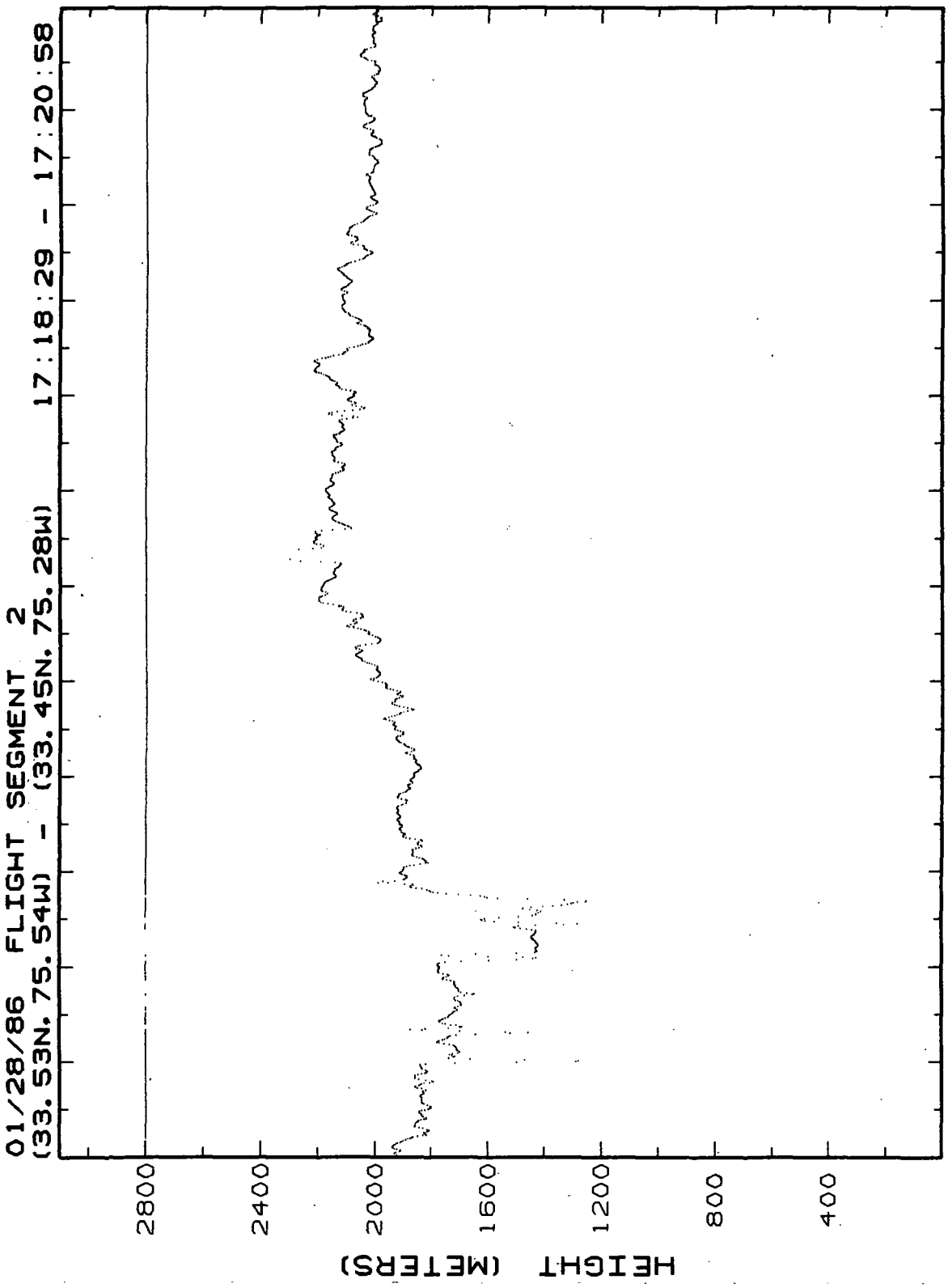

Figure 9.2b. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 2, 24-48 km.

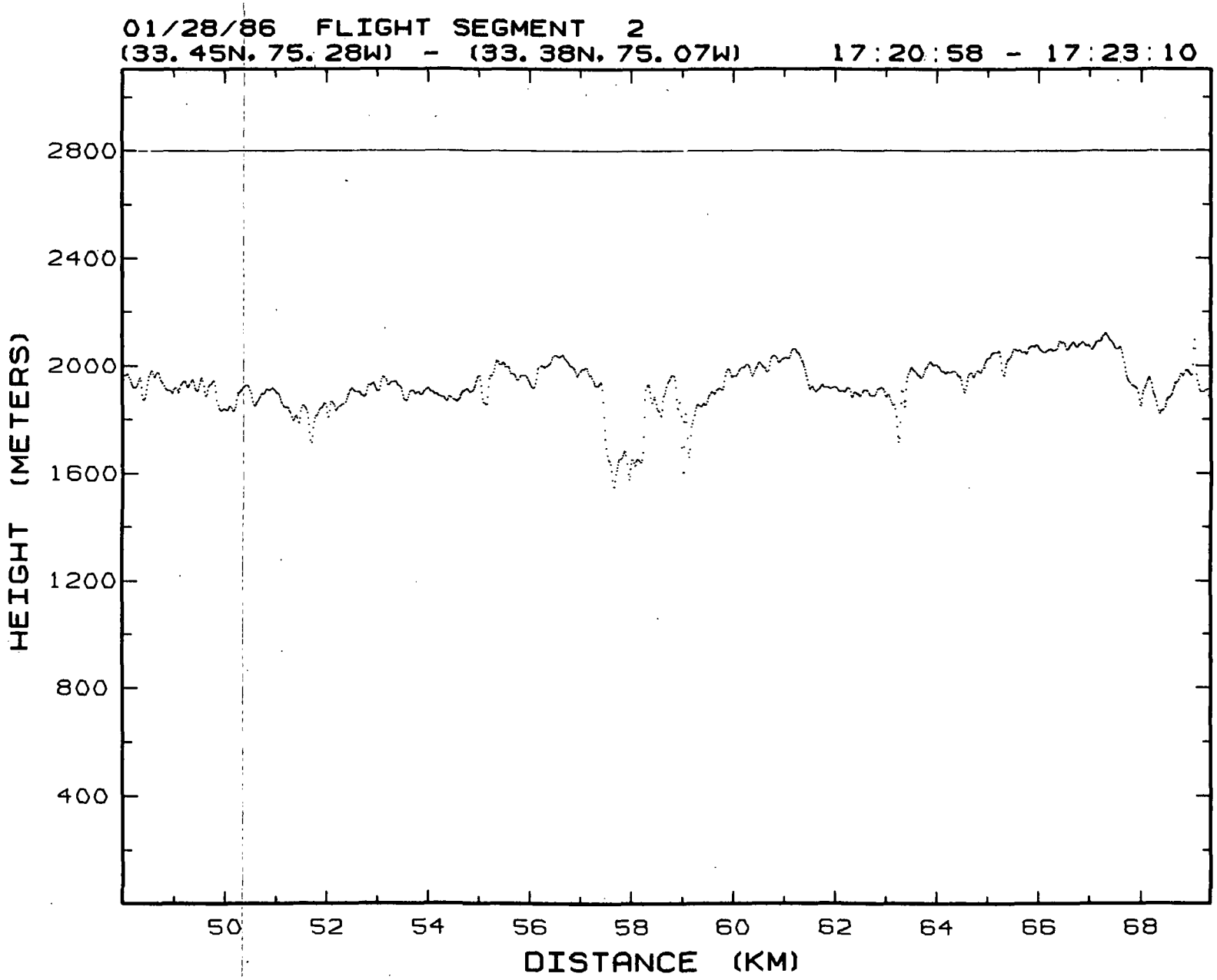

Figure 9.2c. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 2, 48-72 km.

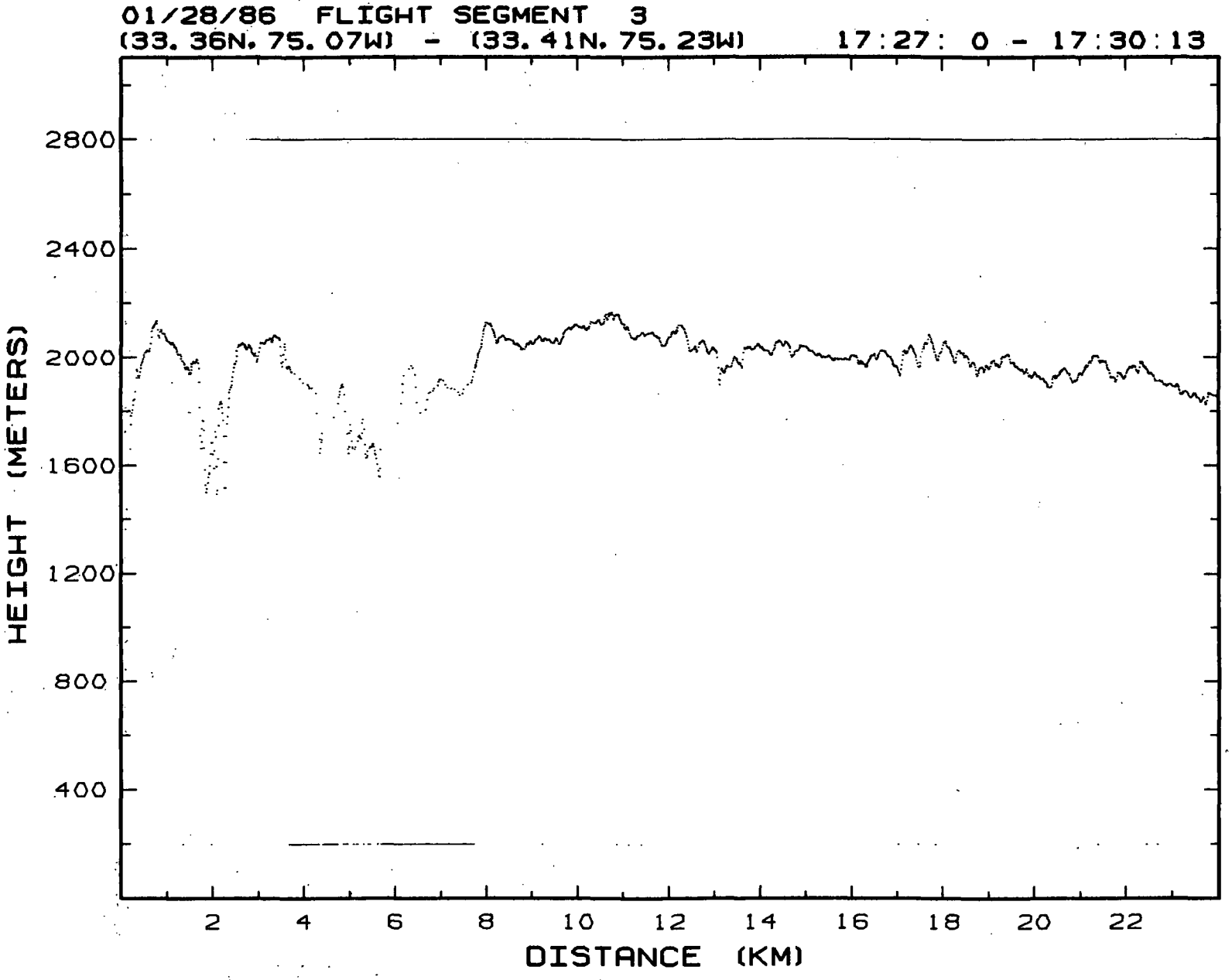

Figure 9.3. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 3, 0-24 km.

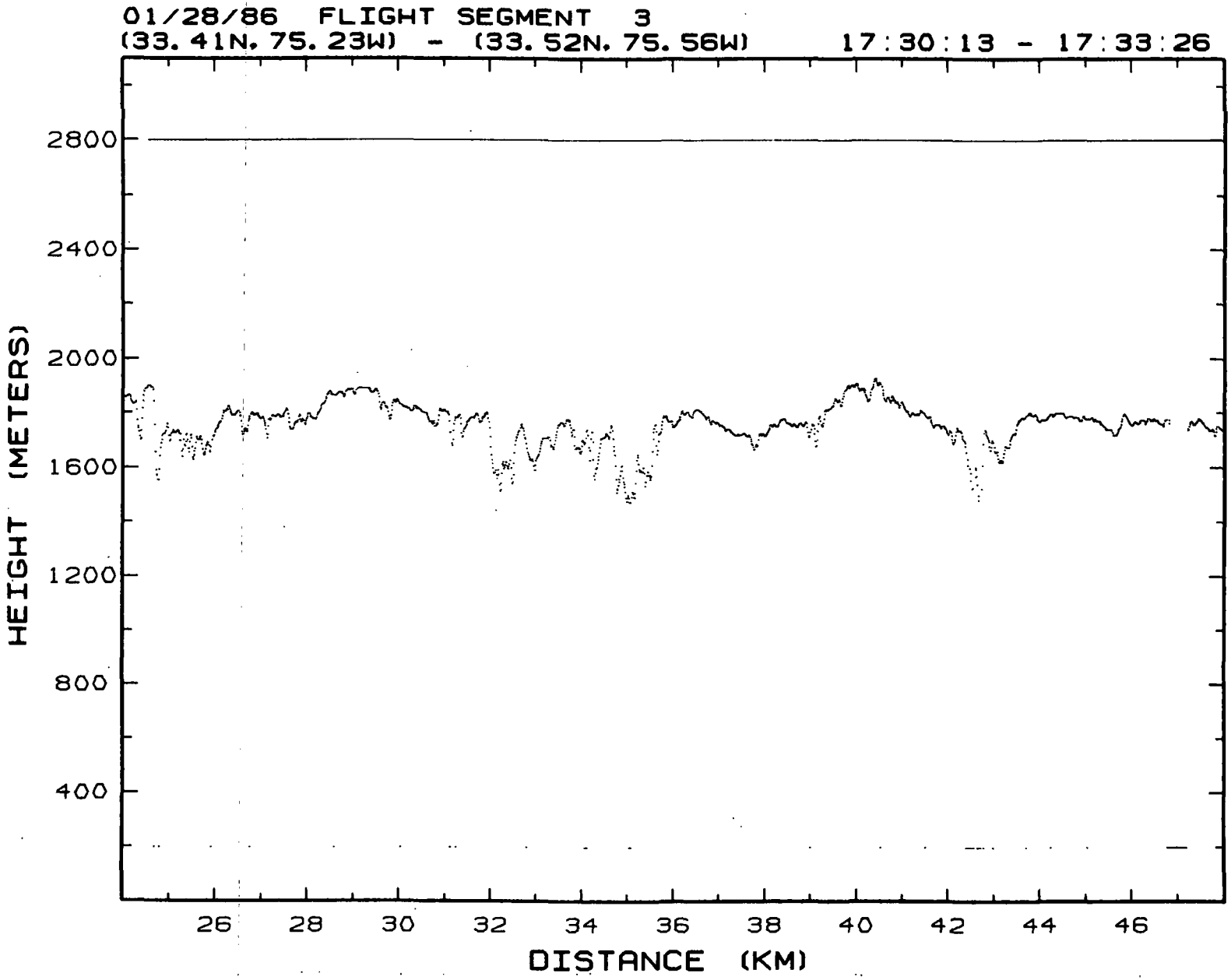

Figure 9.3b. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 3, 24-48 km.

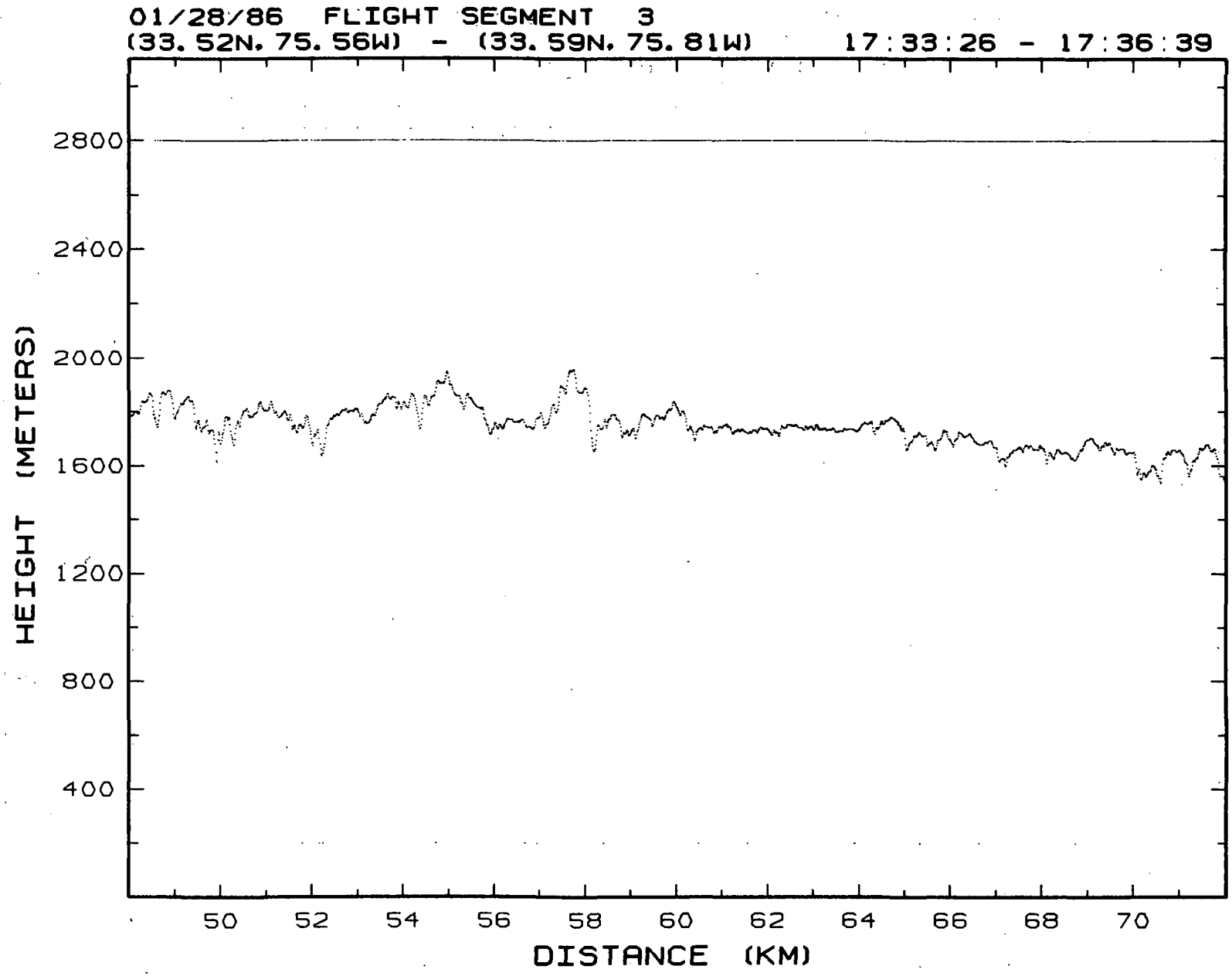

Figure 9.3c. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 3, 48-72 km.

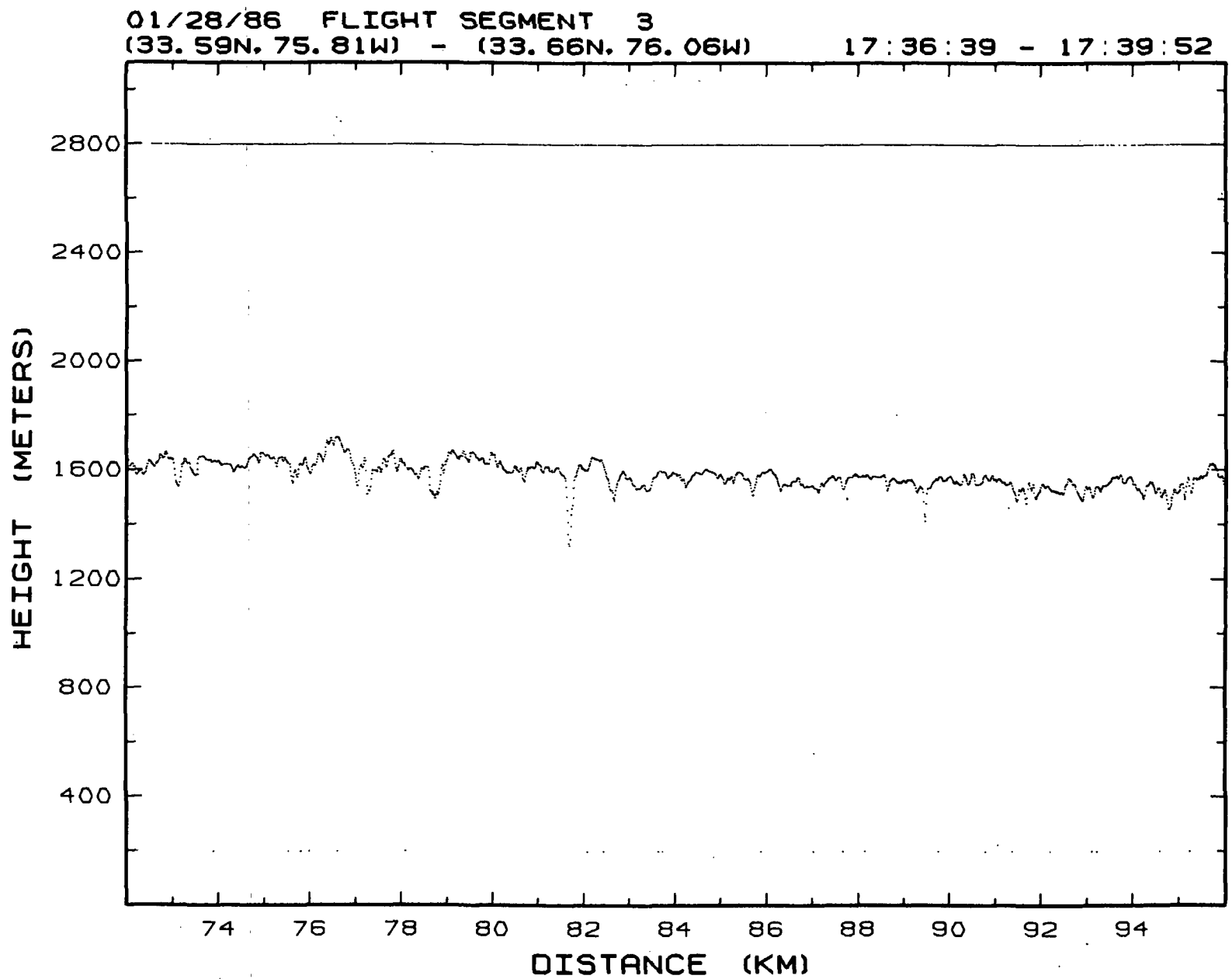

Figure 9.3d. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 3, 72-96 km.

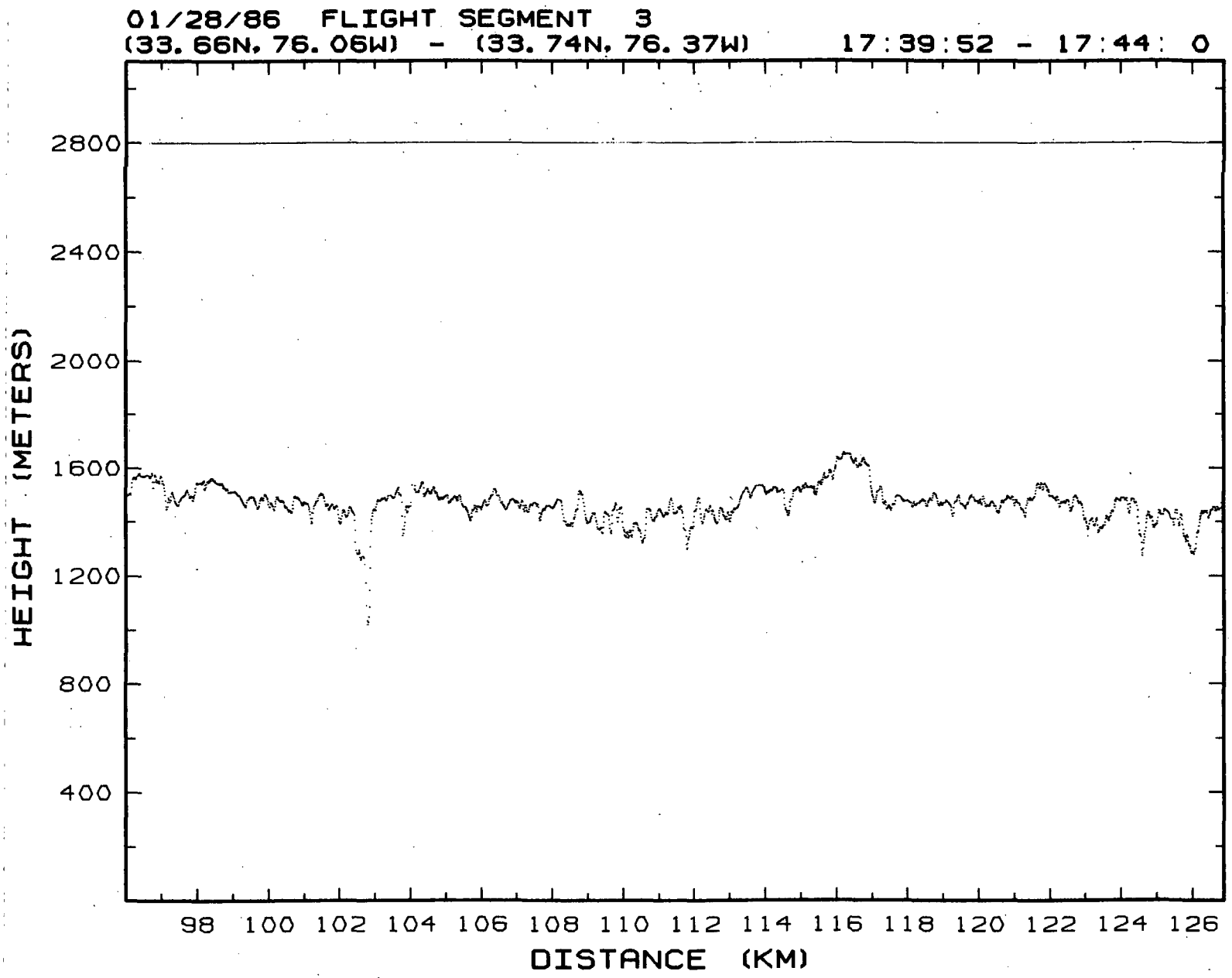

Figure 9.3e. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 3, 96-127 km.

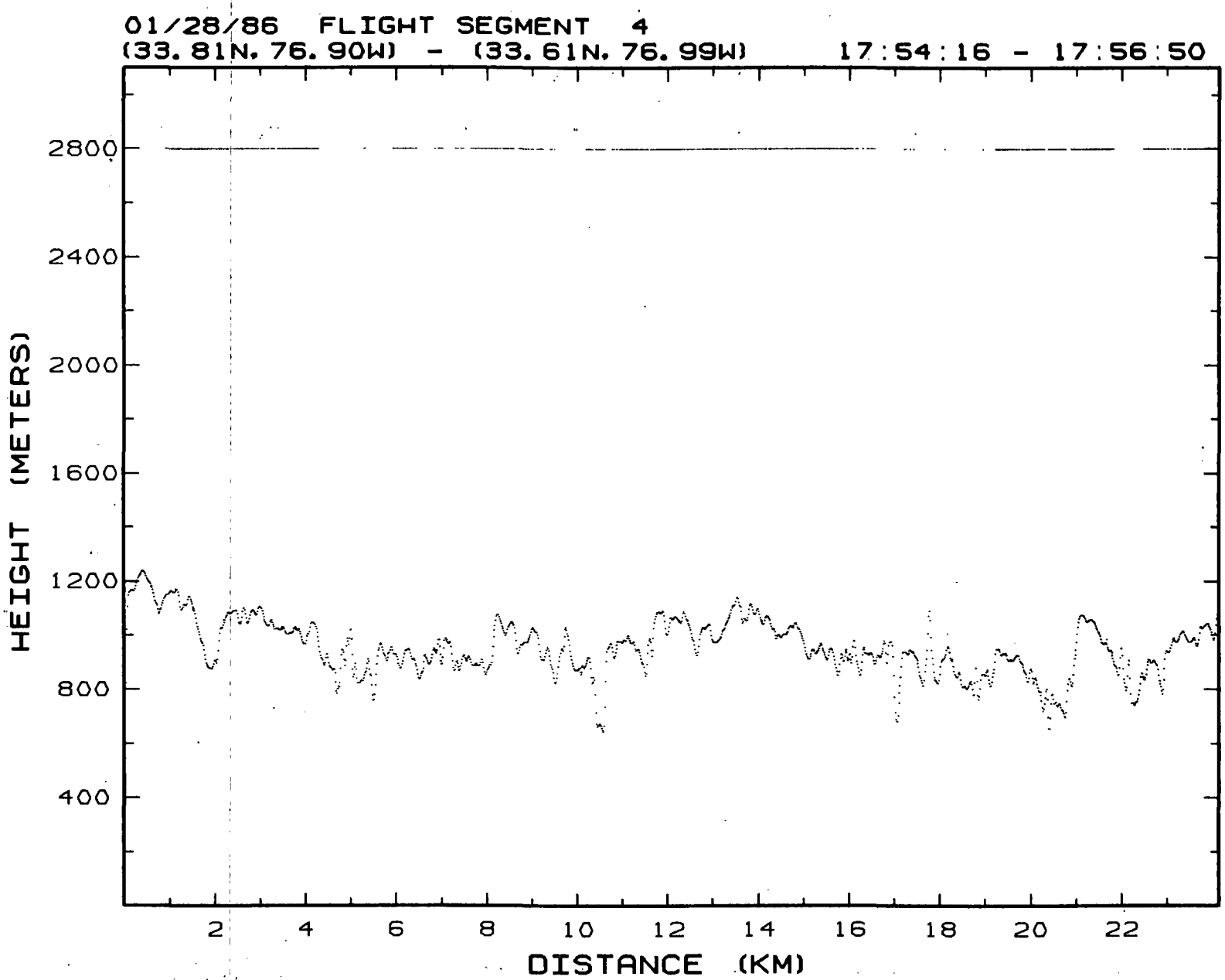

Figure 9.4a. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 4, 0-24 km.

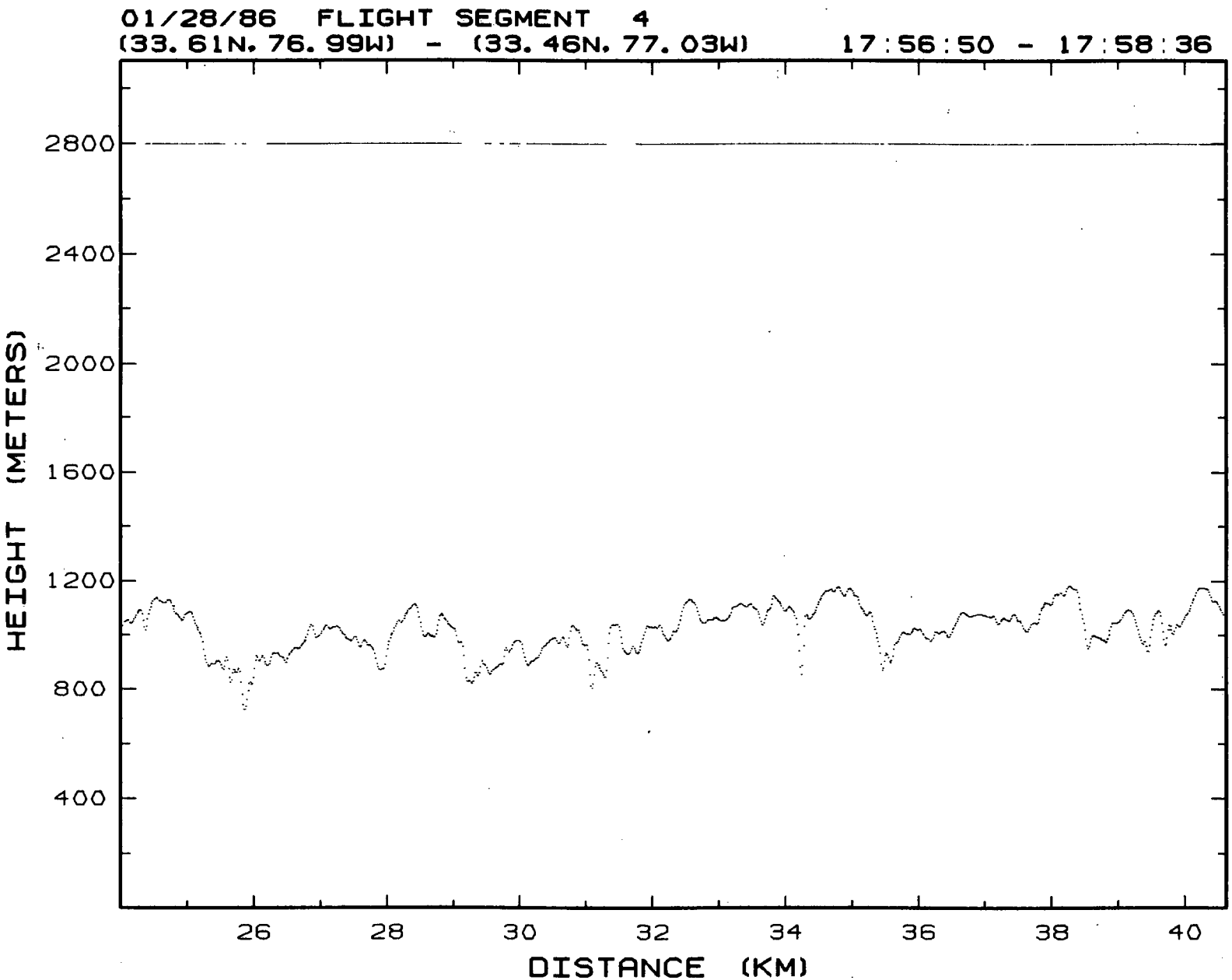

Figure 9.4b. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 4, 24-41 km.

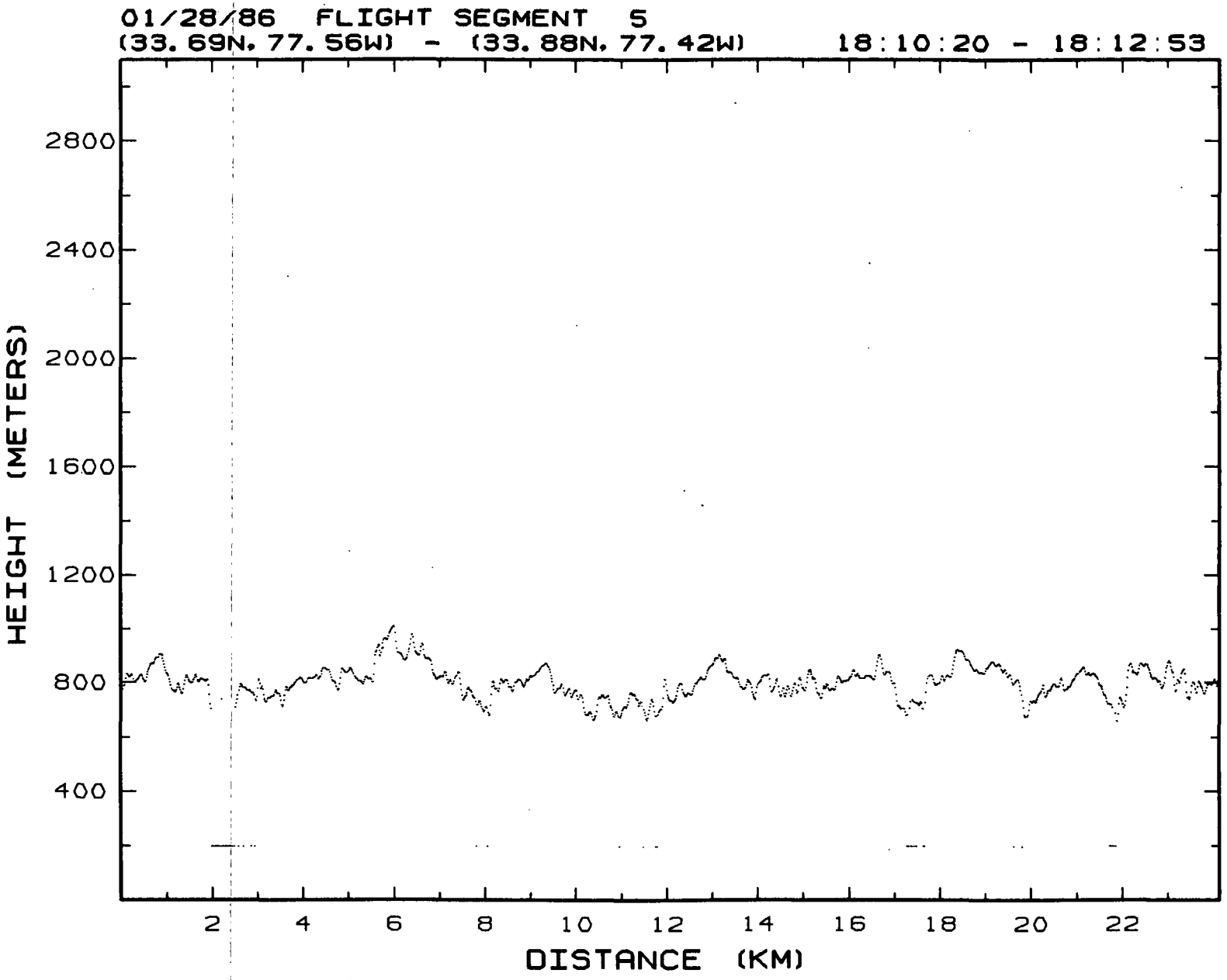

Figure 9.5a. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 5, 0-24 km.

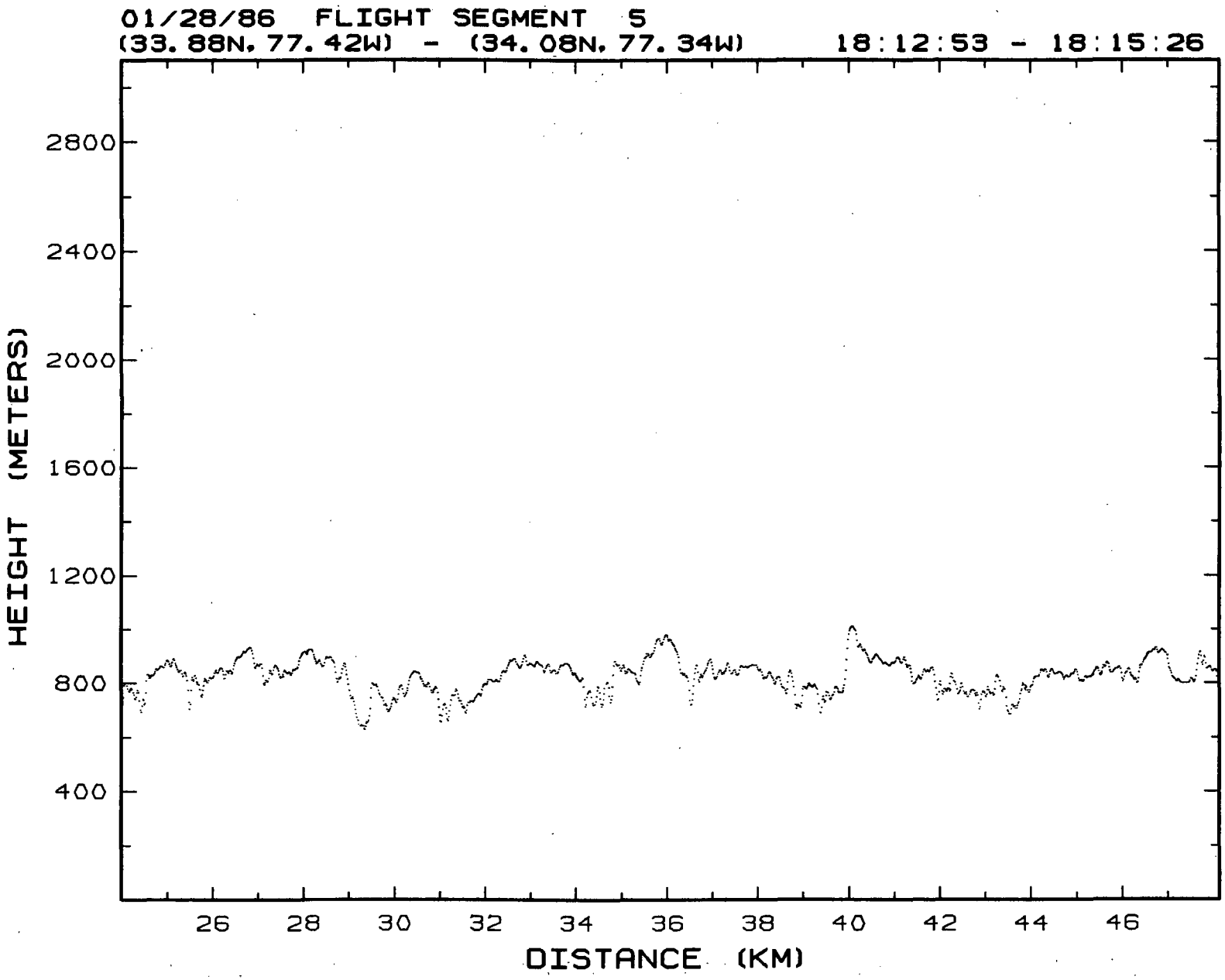

Figure 9.5b. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 5, 24-48 km.

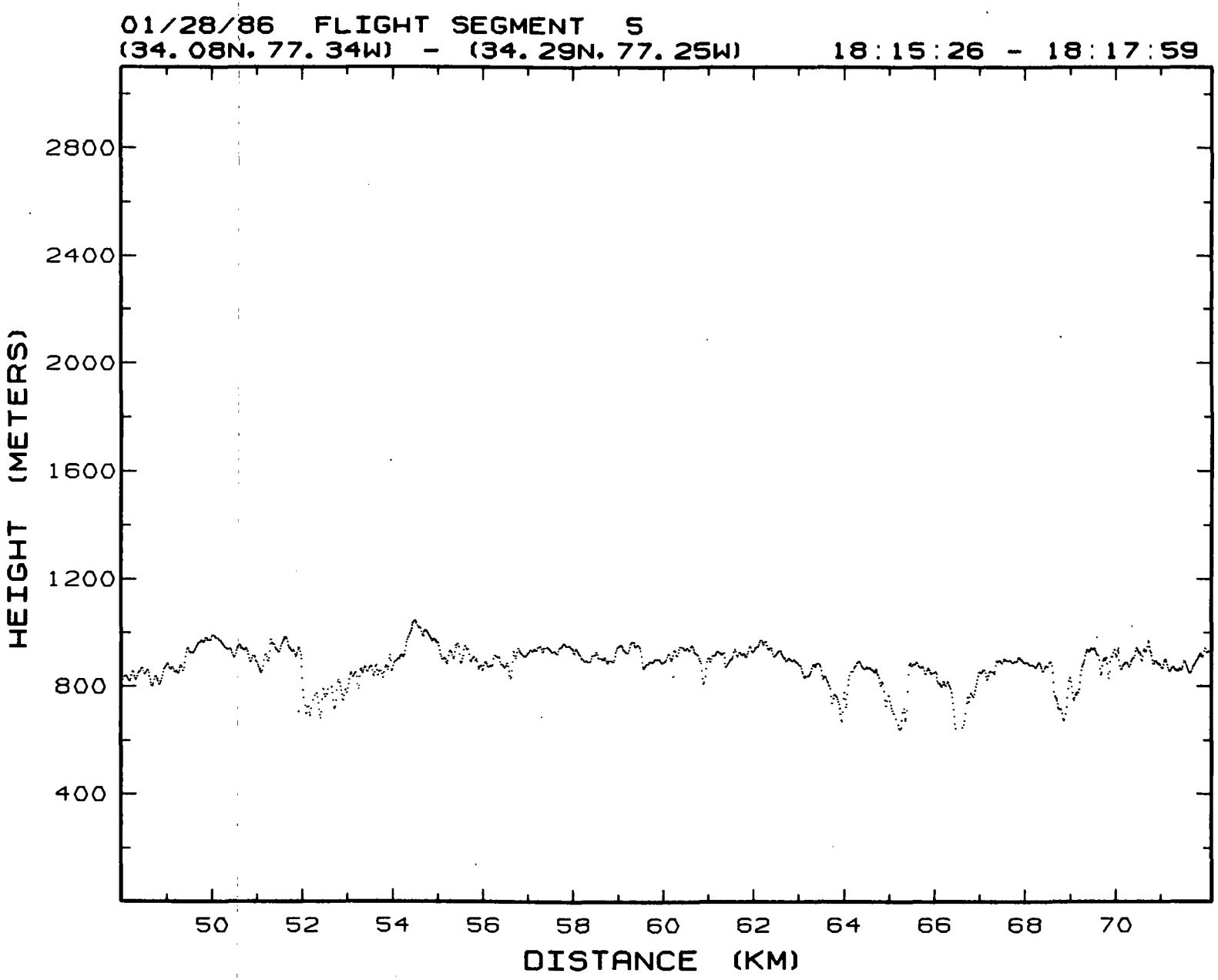

Figure 9.5c. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 5, 48-72 km.

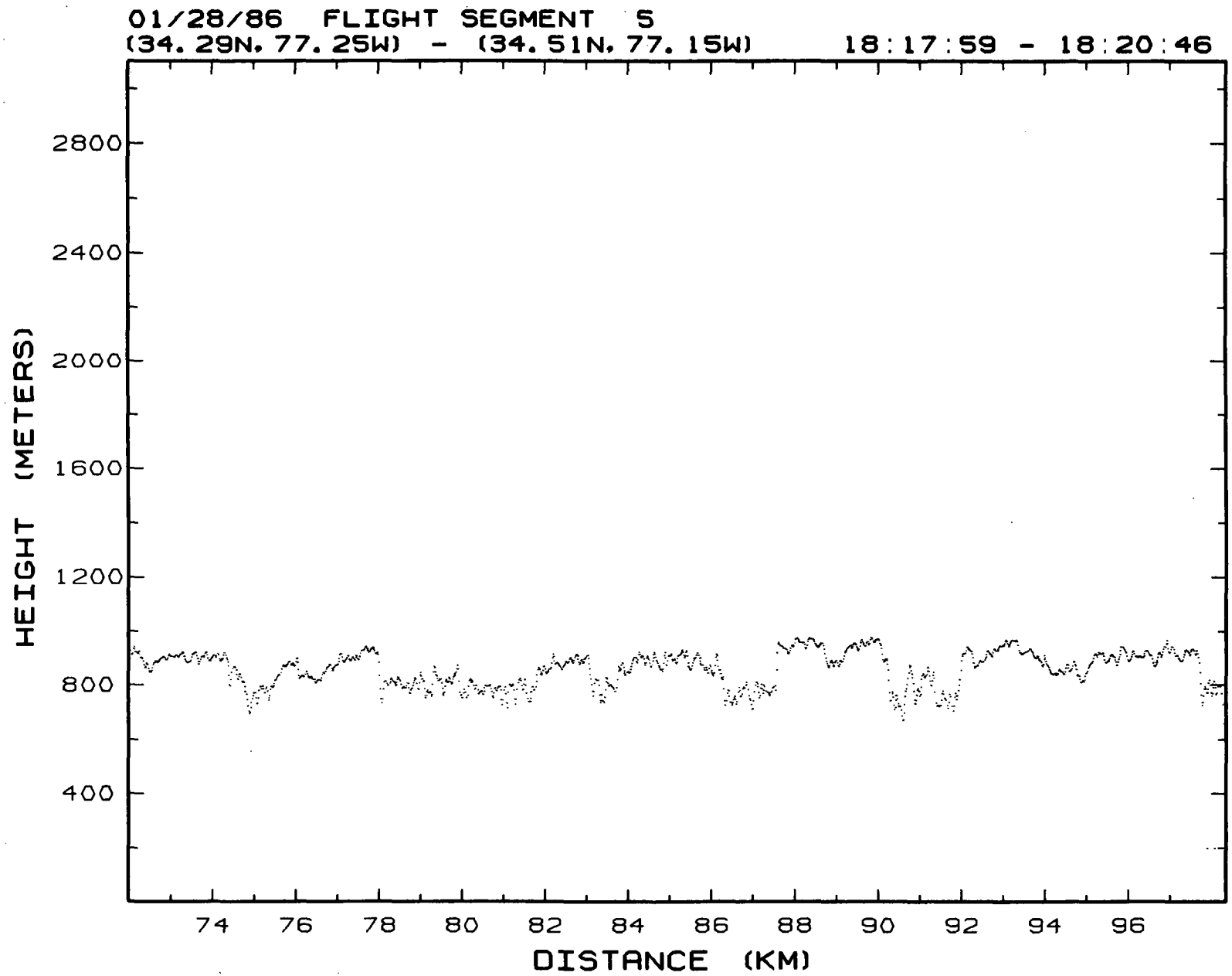

Figure 9.5d. Lidar retrieved MABL heights for Flight 1, 28-Jan-86, flight segment 5, 72-98 km.

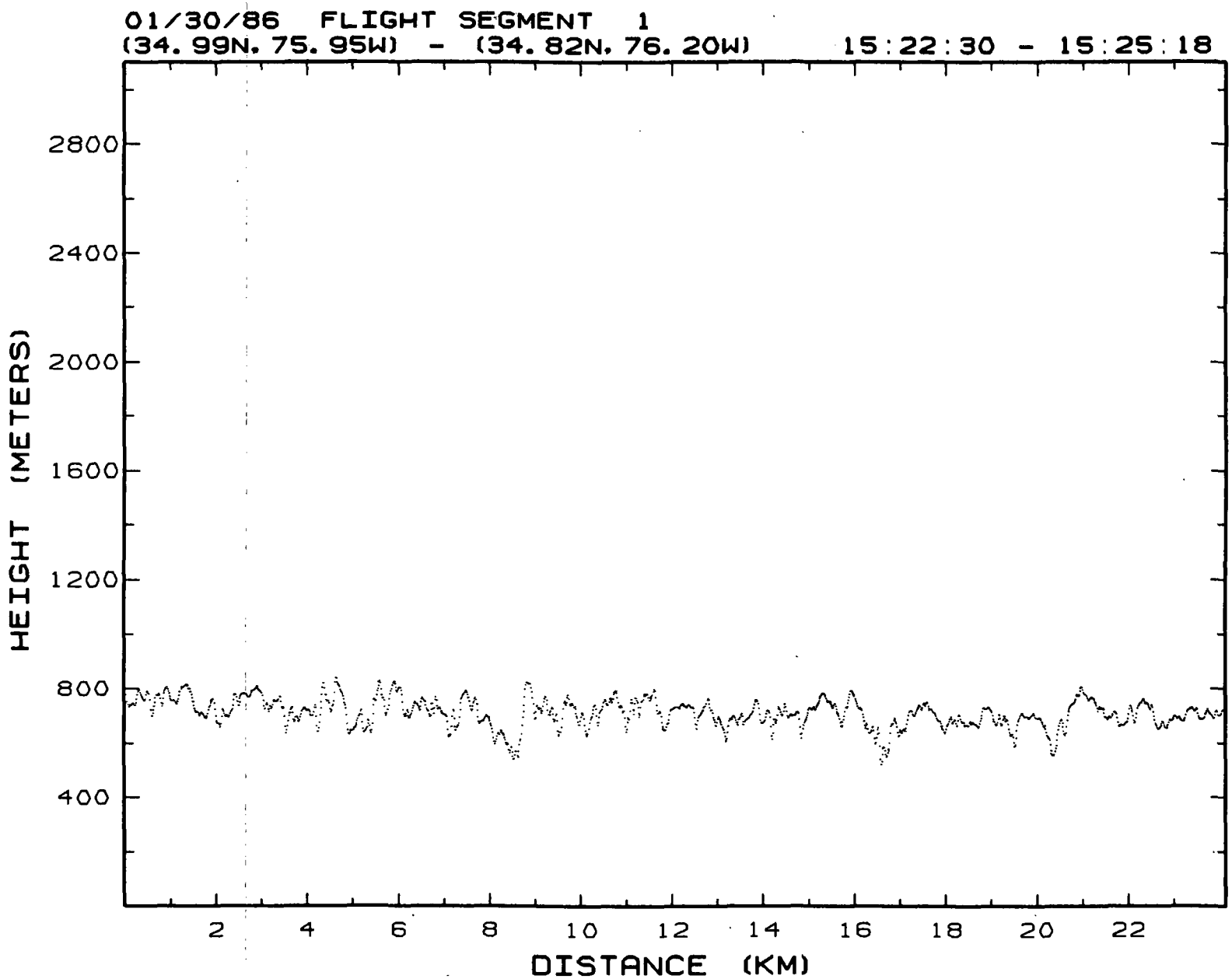

Figure 10.1a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 1, 0-24 km.

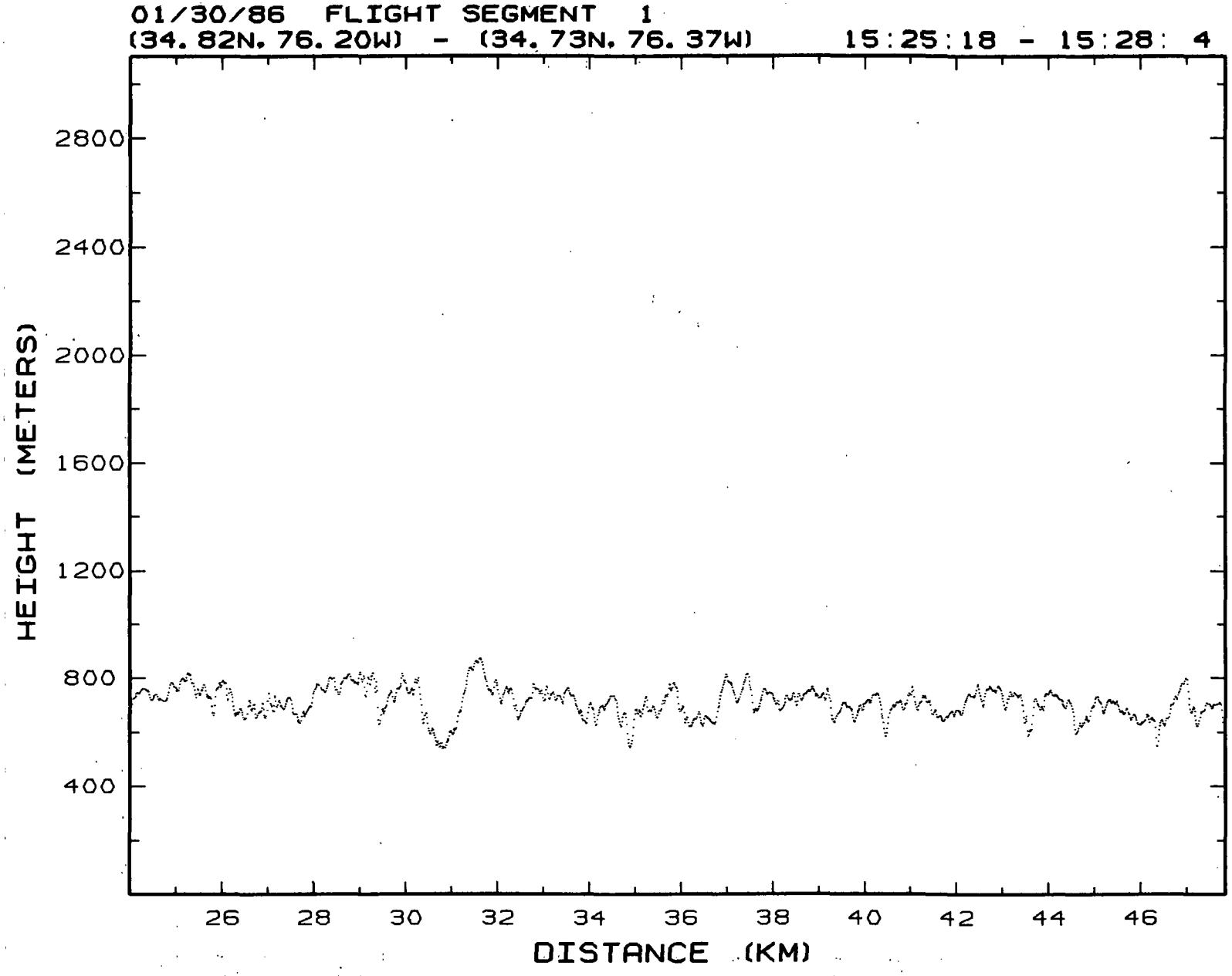

Figure 10.1b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 1, 24-48 km.

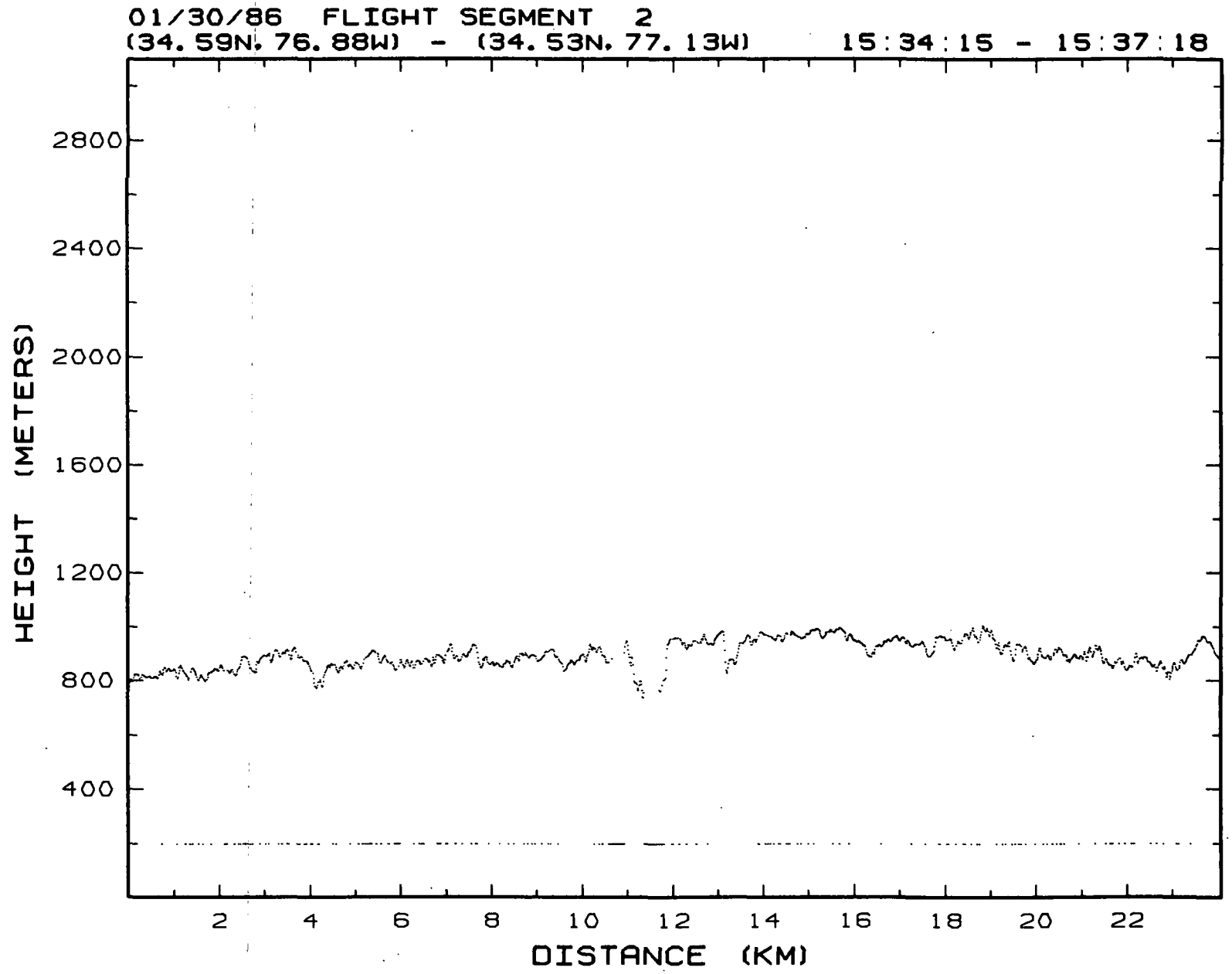

Figure 10.2a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 2, 0-24 km.

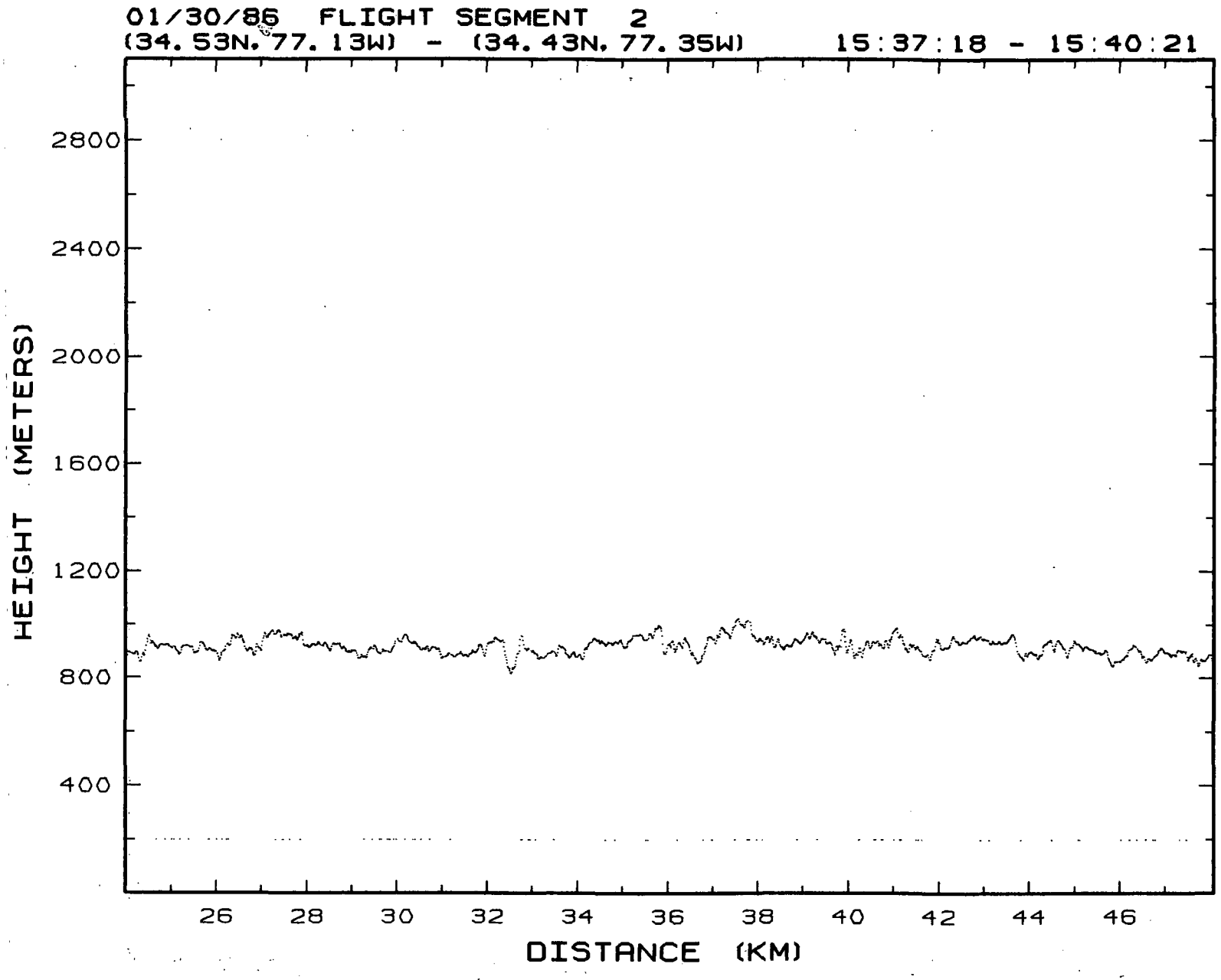

Figure 10.2b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 2, 24-48 km.

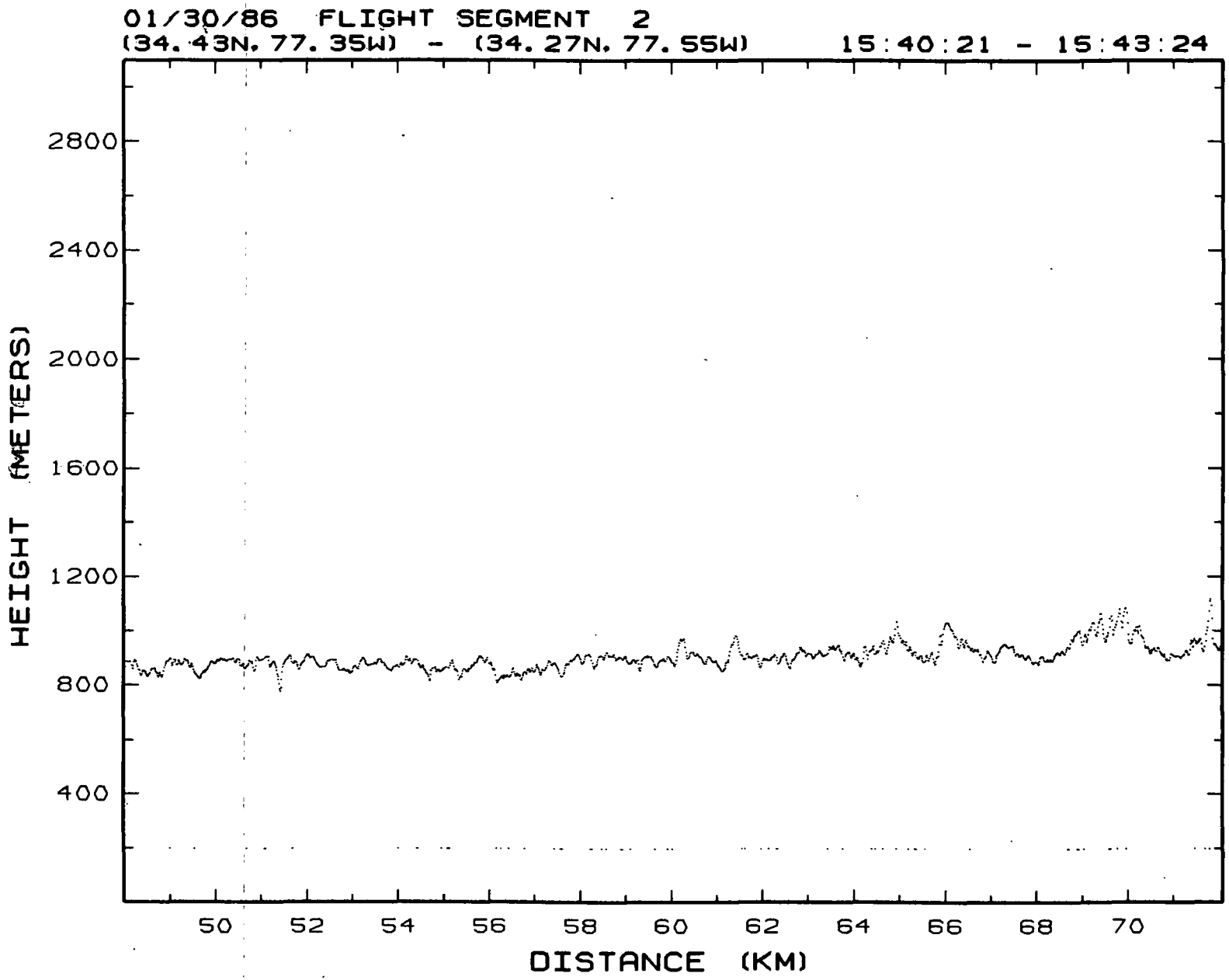

Figure 10.2c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 2, 48-72 km.

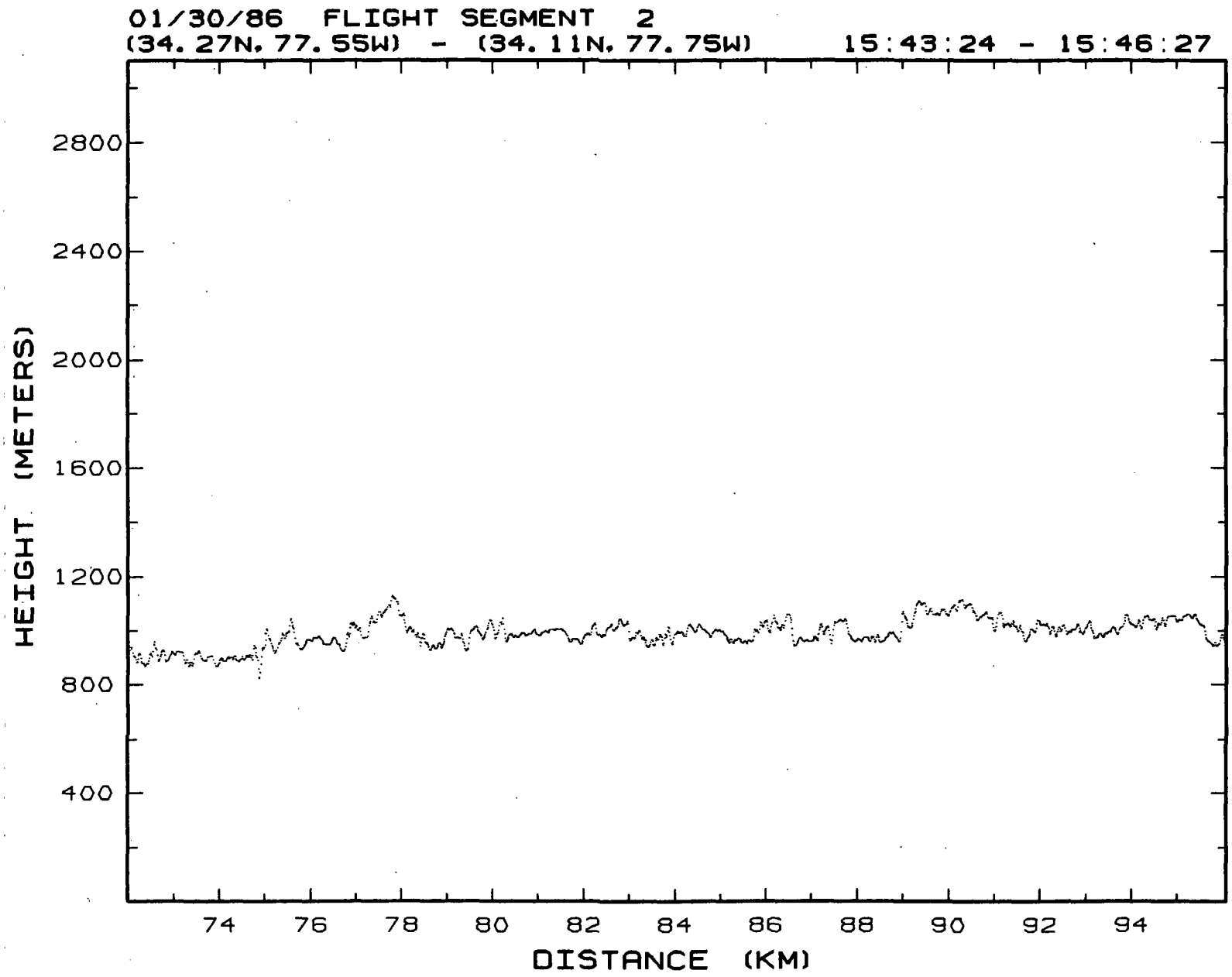

Figure 10.2d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 2, 72-96 km.

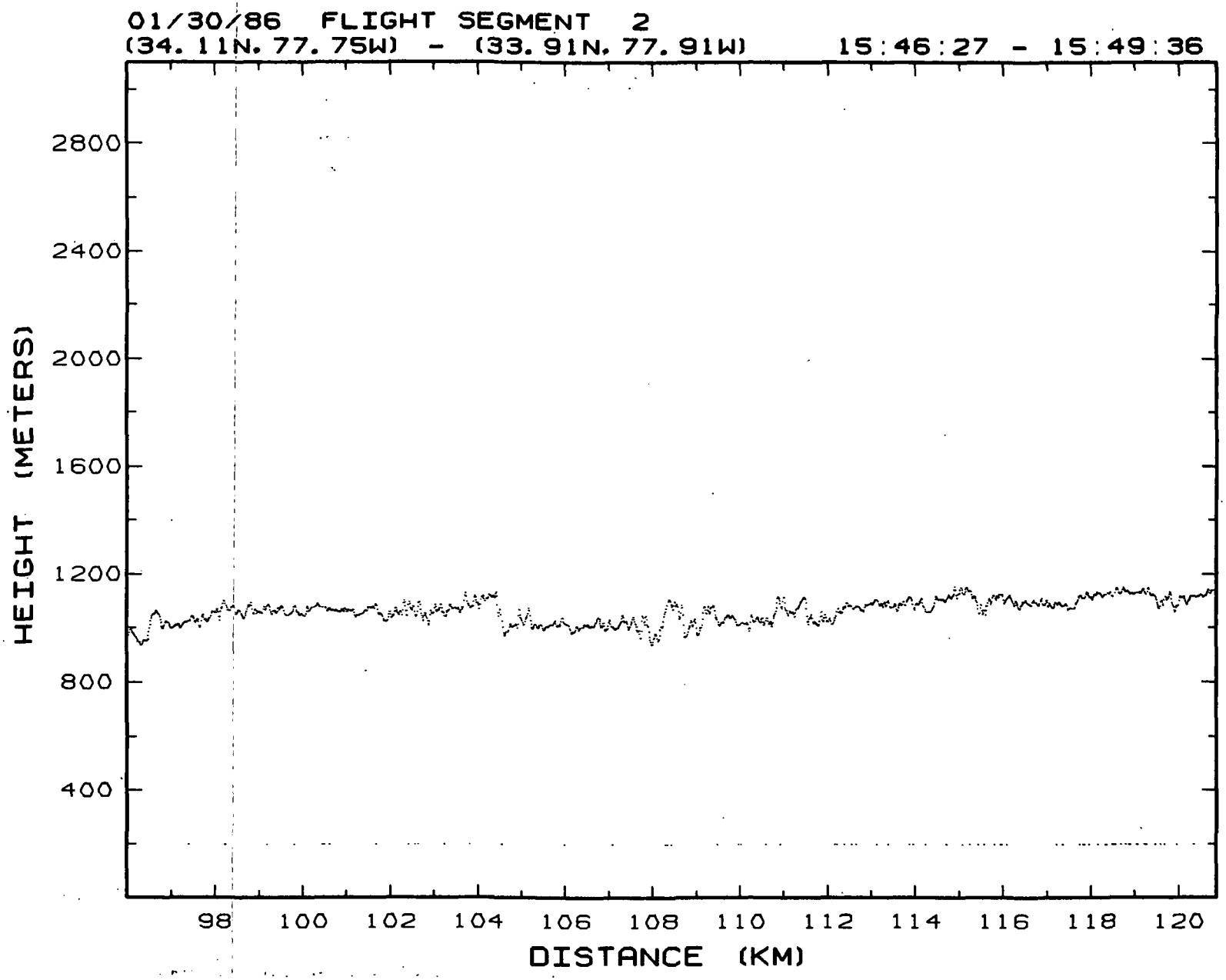

Figure 10.2e. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 2, 96-120 km.

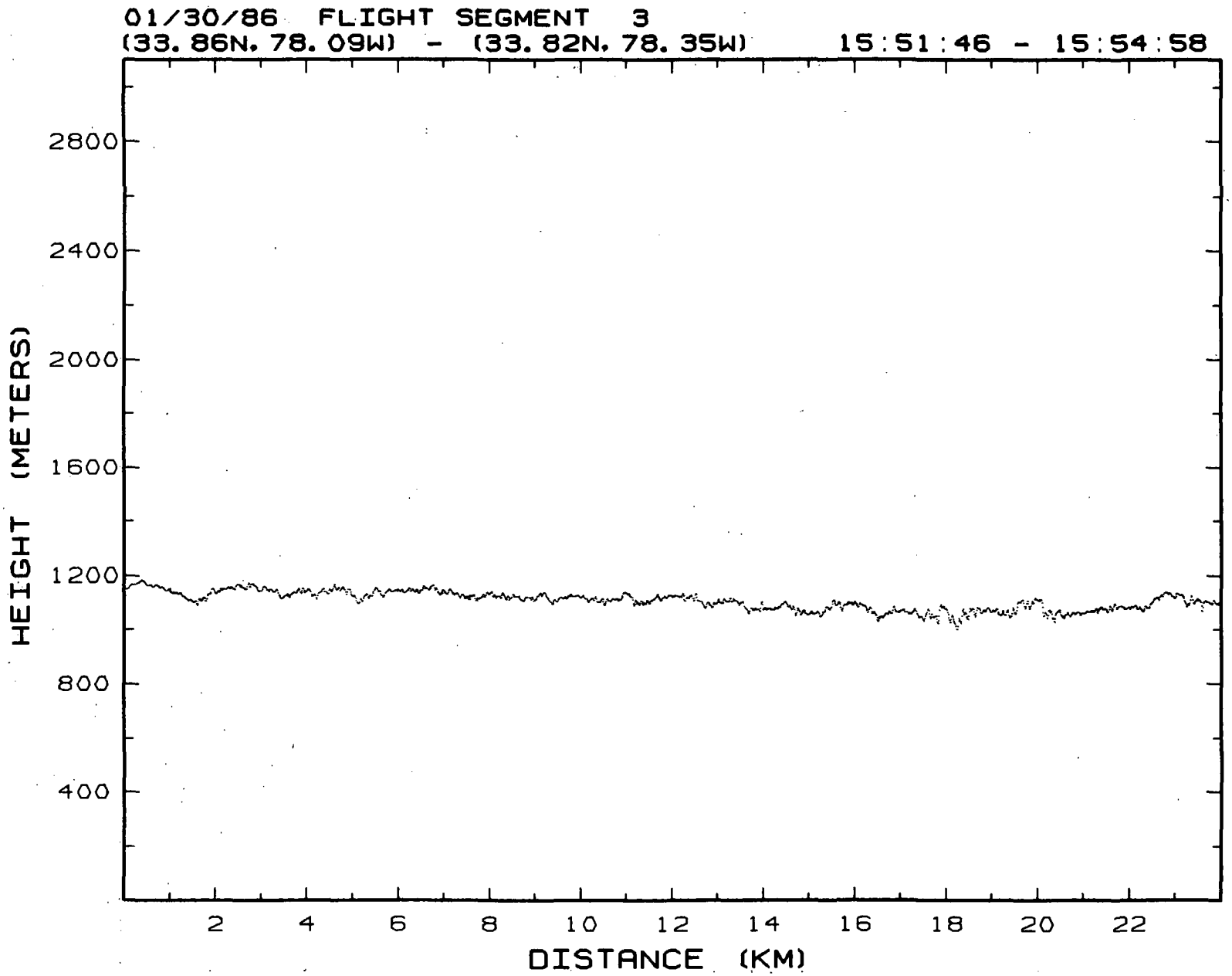

Figure 10.3a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 3, 0-24 km.

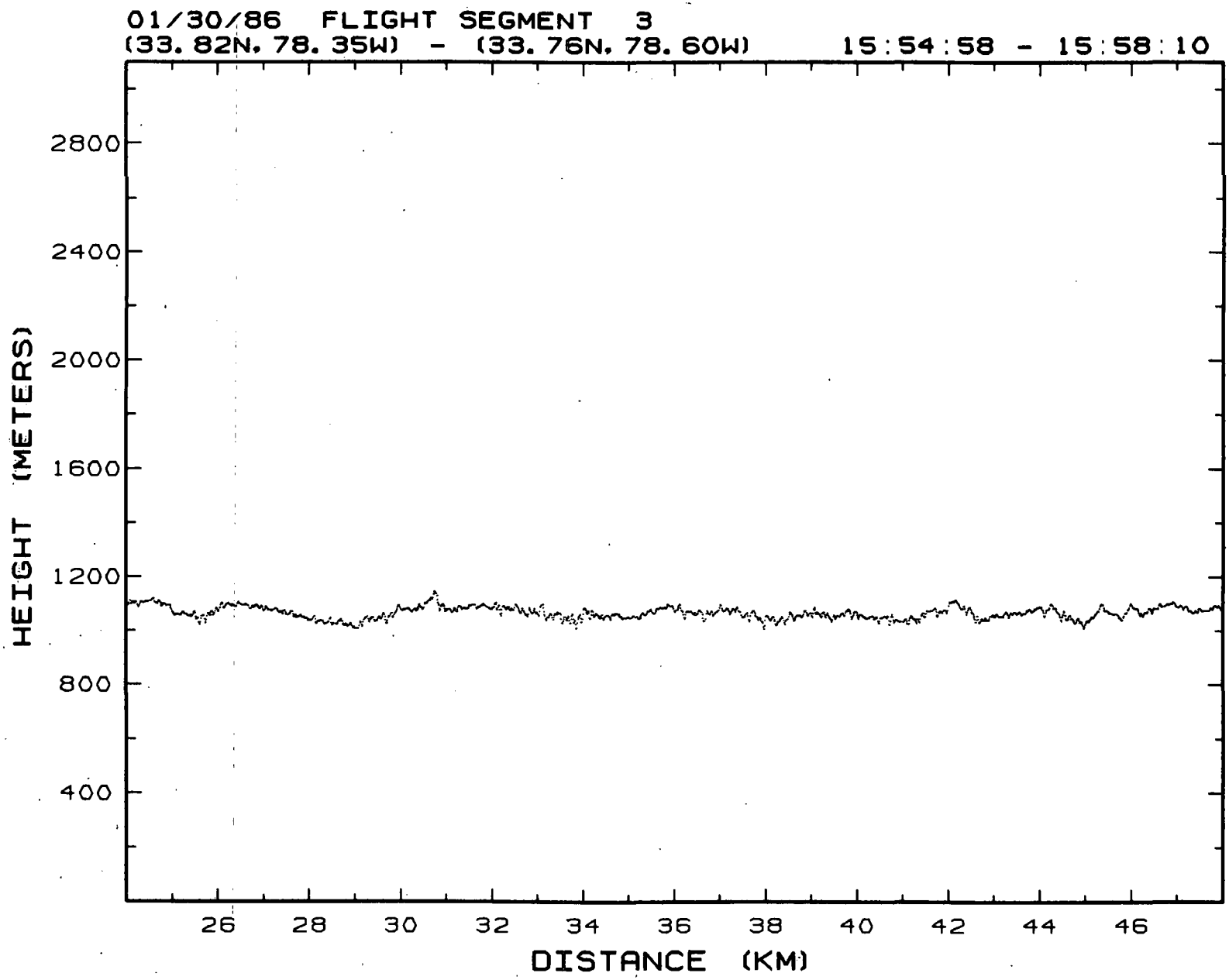

Figure 10.3b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 3, 24-48 km.

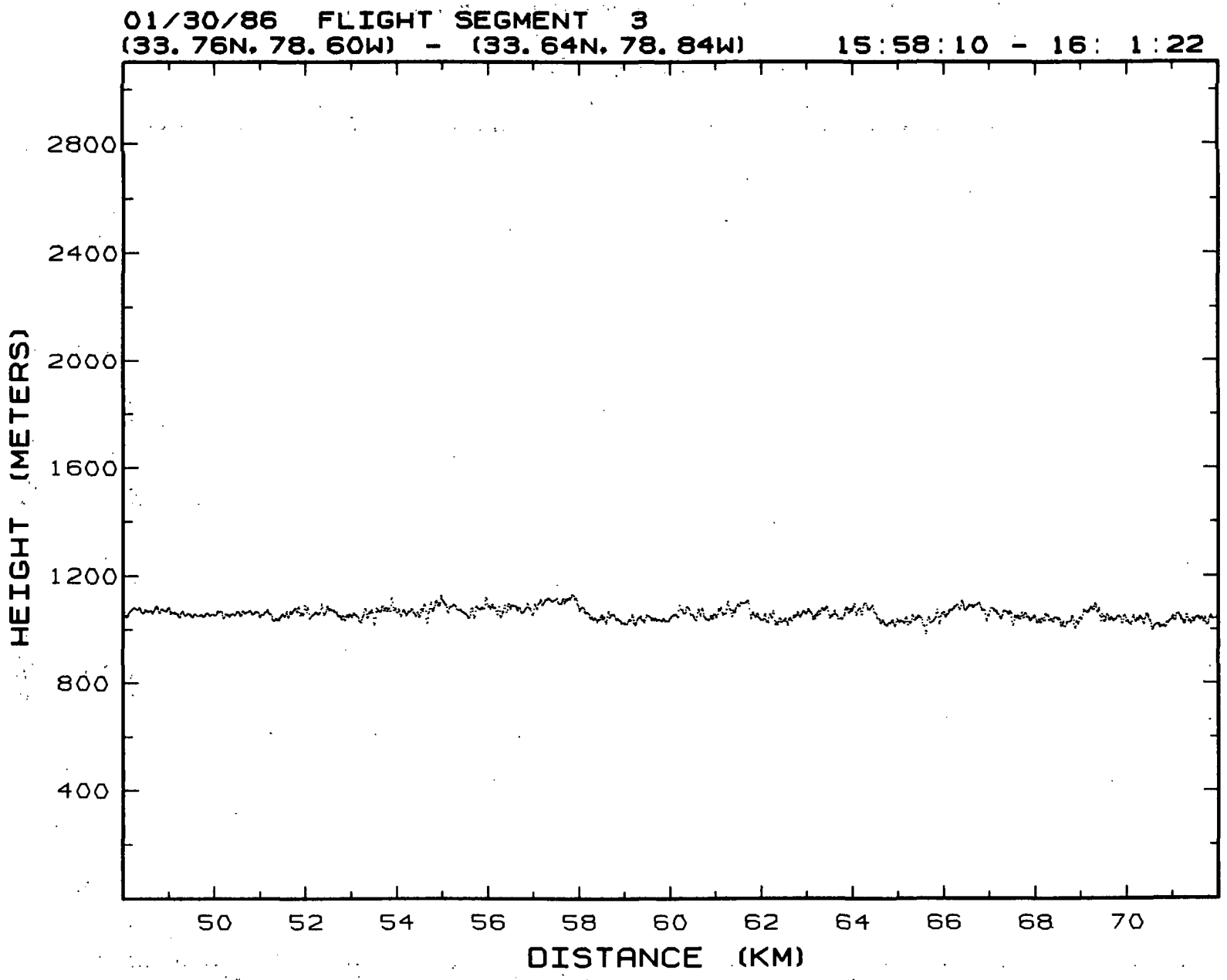

Figure 10.3c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 3, 48-72 km.

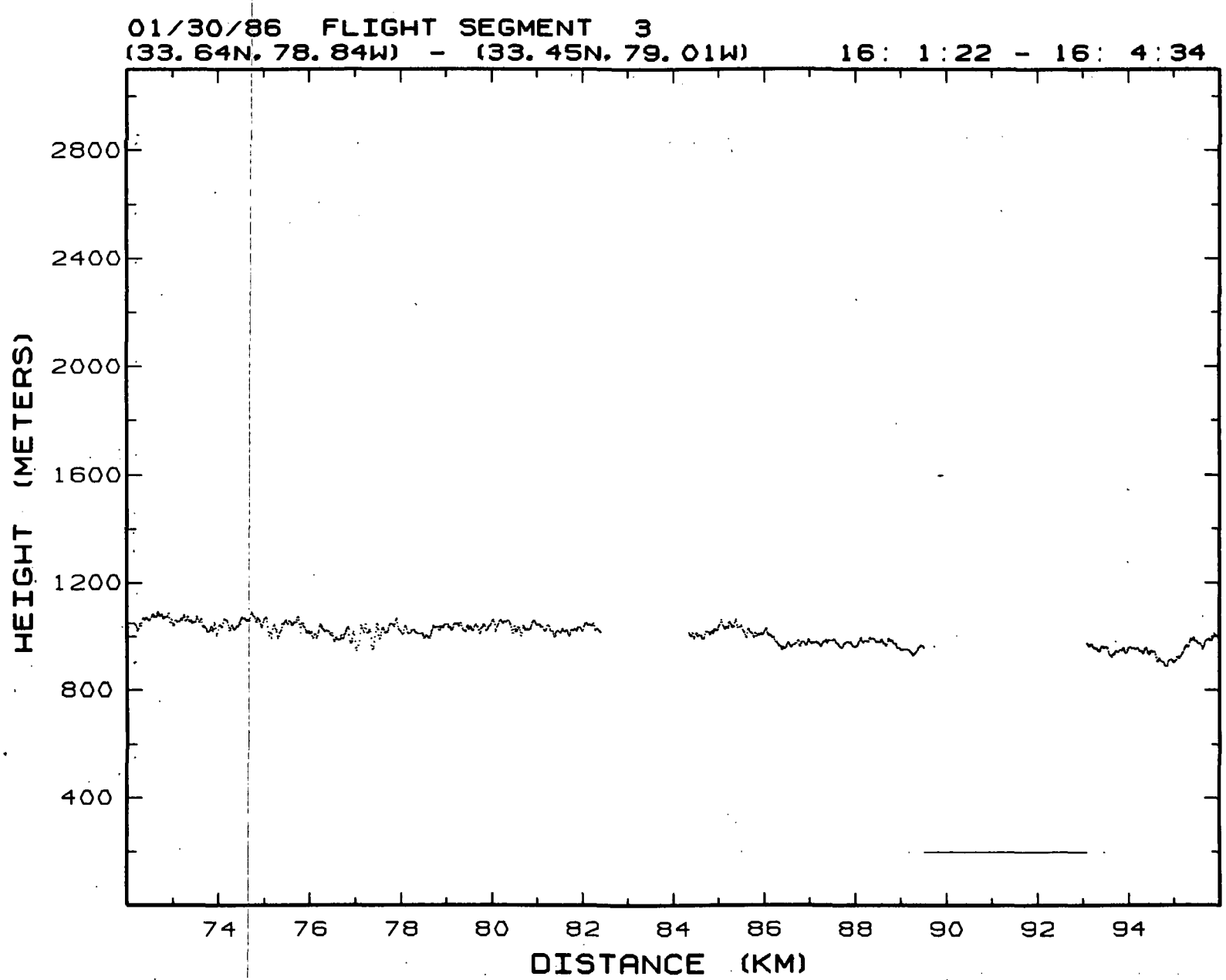

Figure 10.3d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 3, 72-96 km.

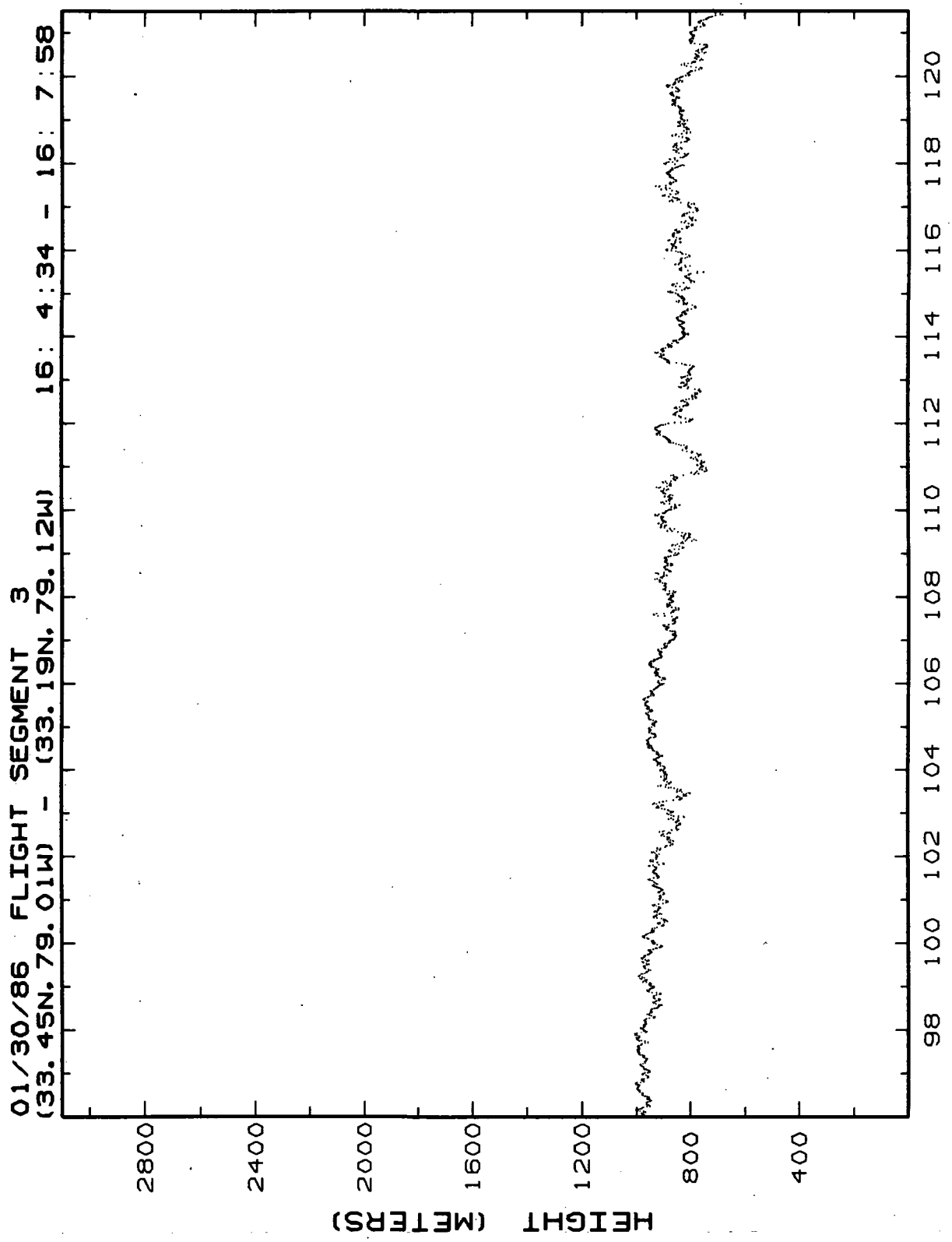

Figure 10.3e. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 3, 96-120 km.

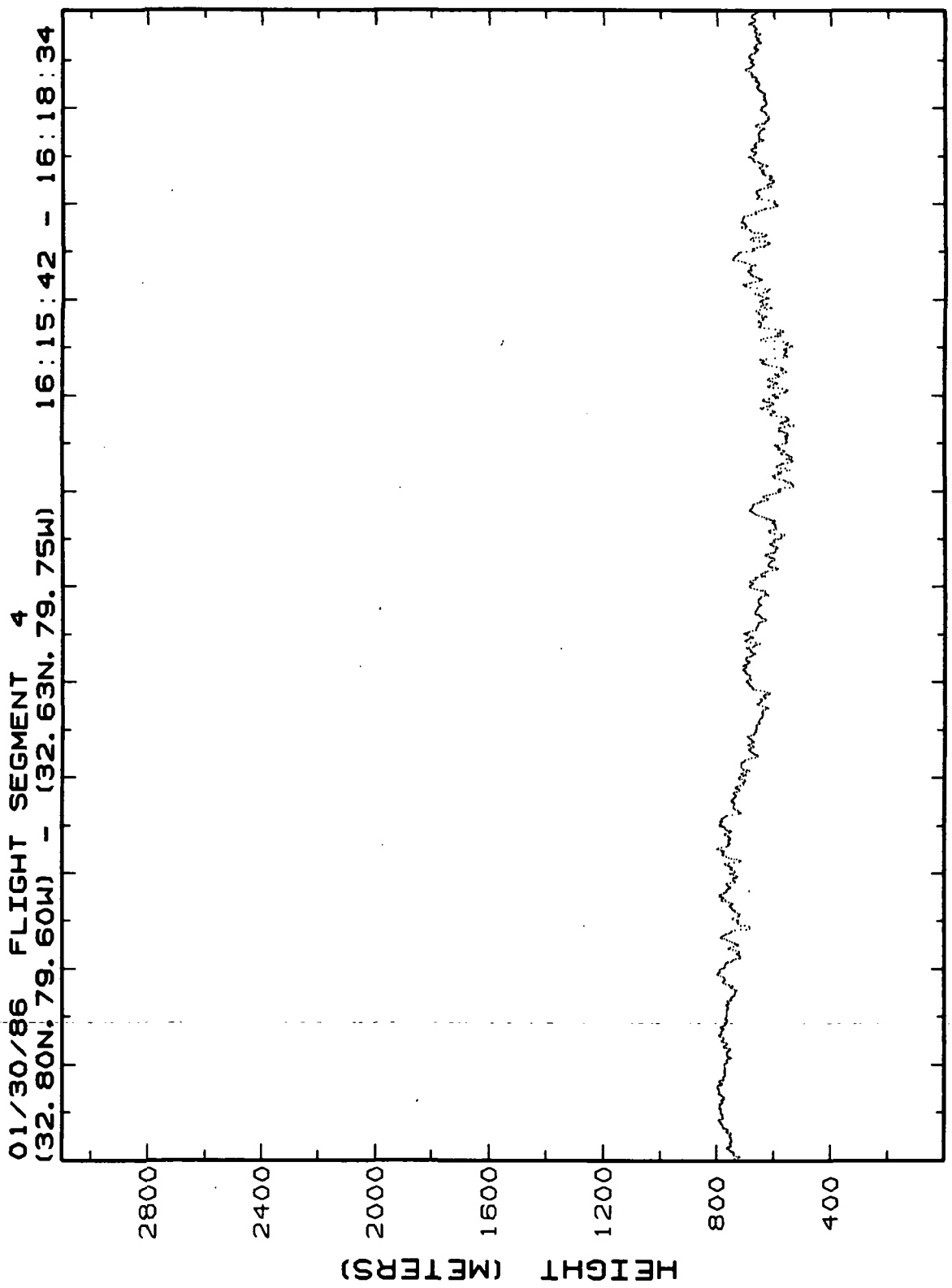

Figure 10.4a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 4, 0-24 km.

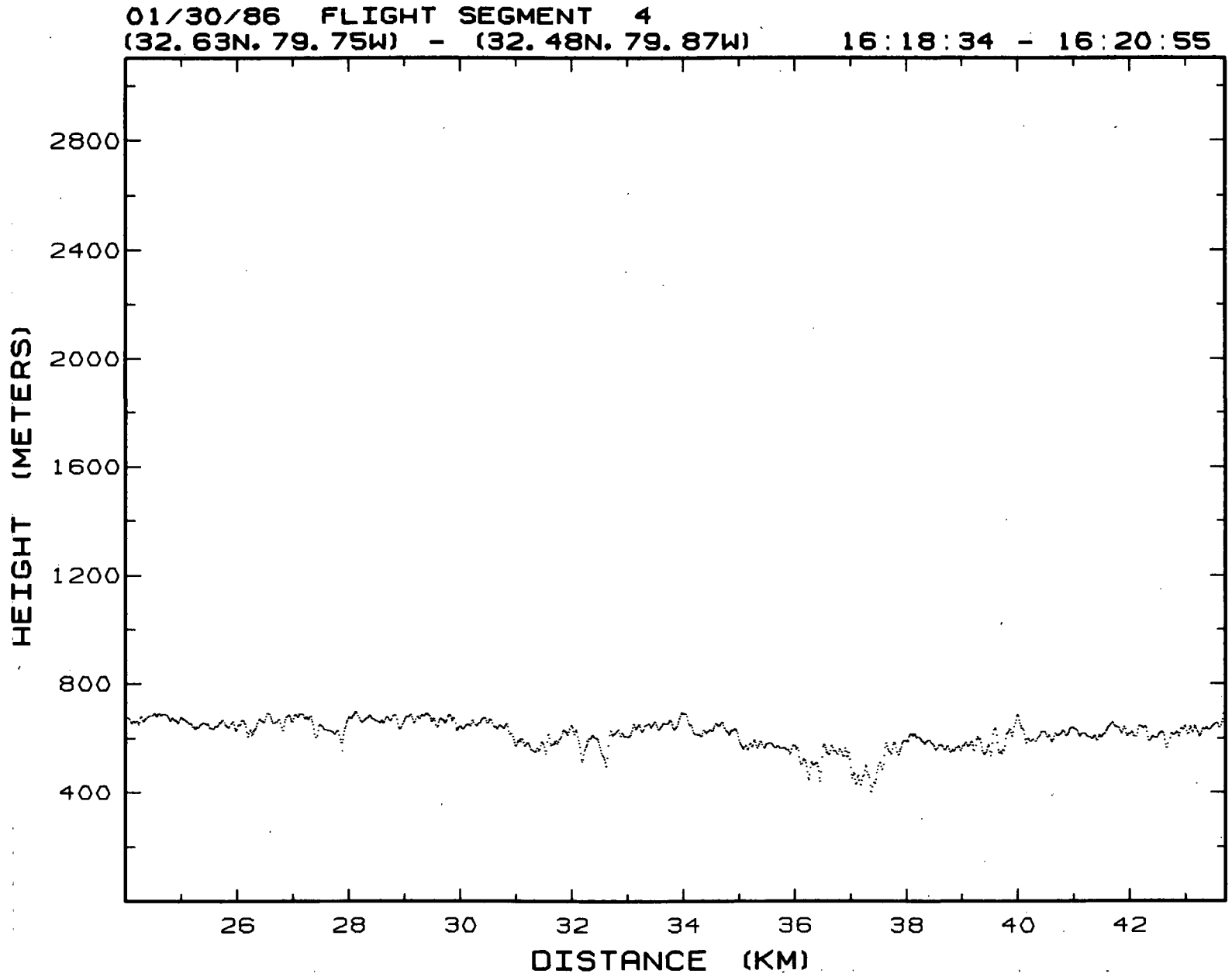

Figure 10.4b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 4, 24-48 km.

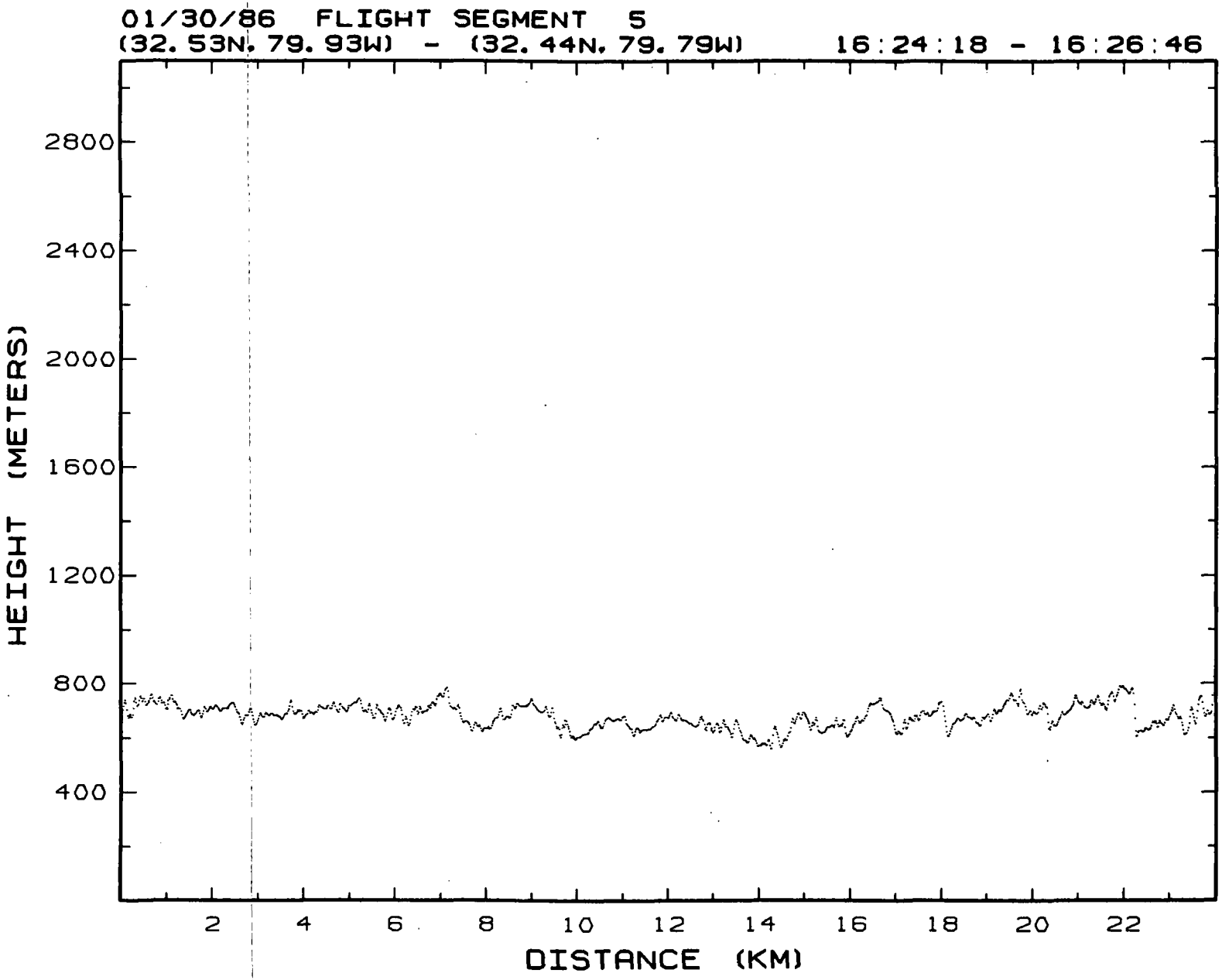

Figure 10.5a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 0-24 km.

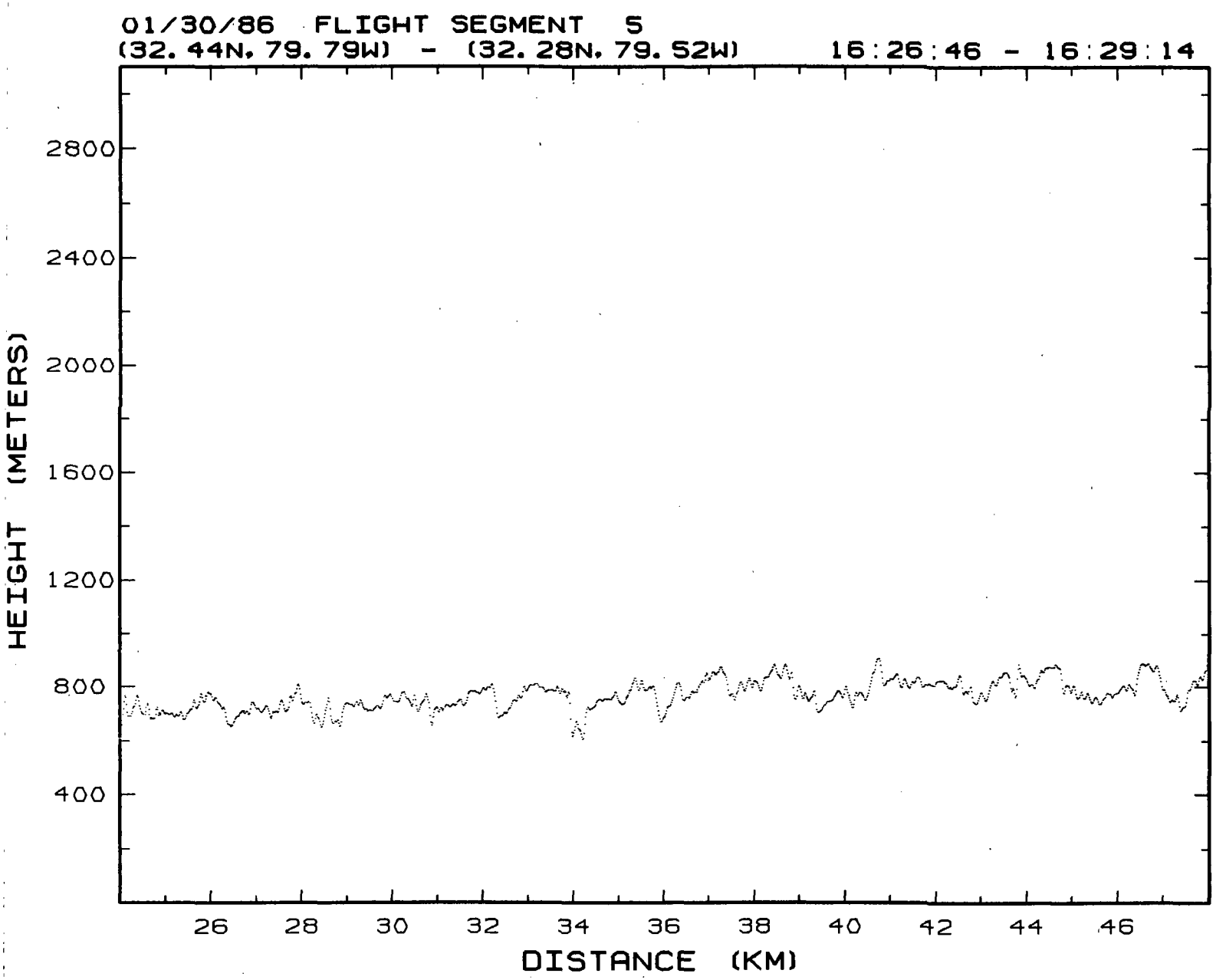

Figure 10.5b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 24-48 km.

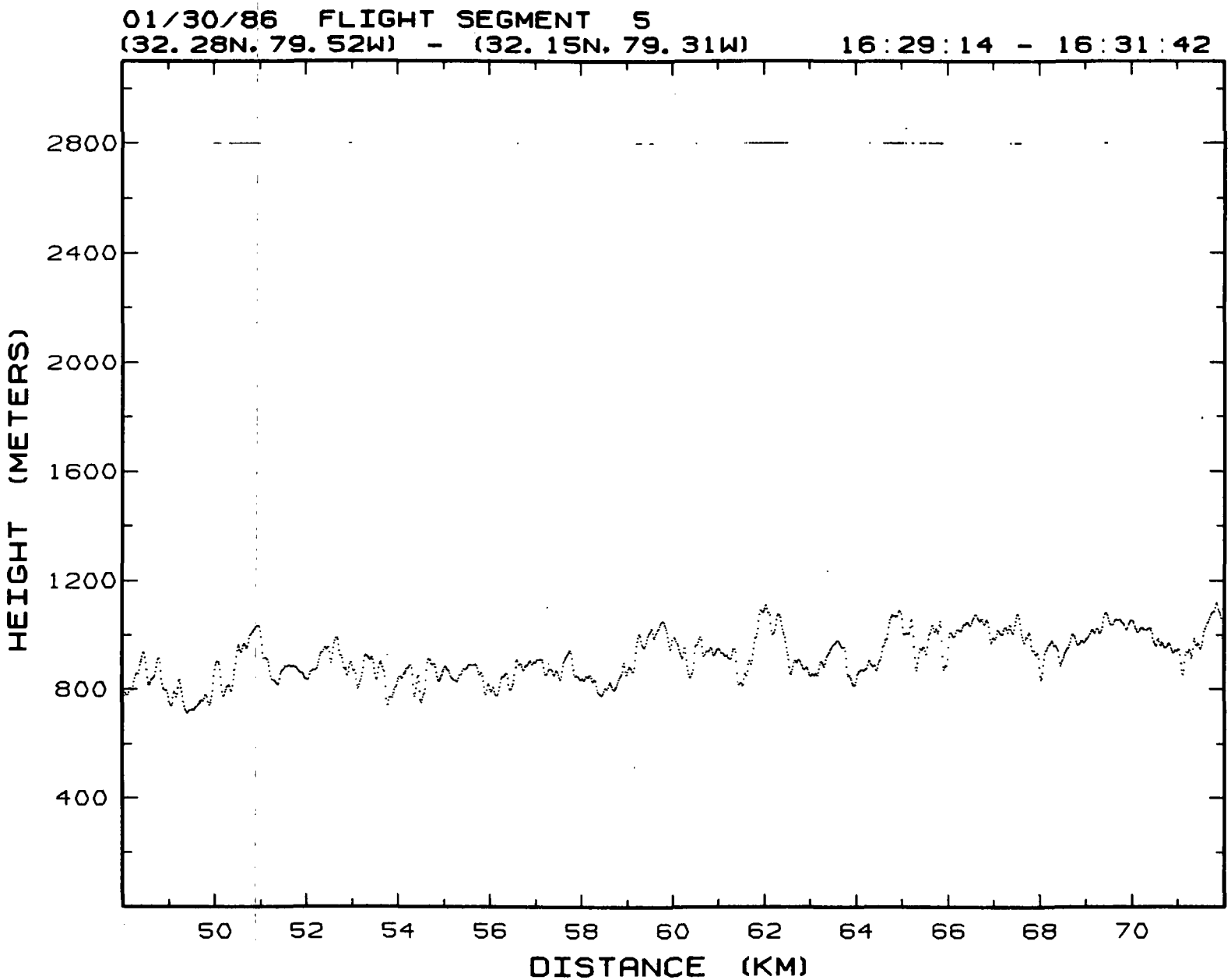

Figure 10.5c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 48-72 km.

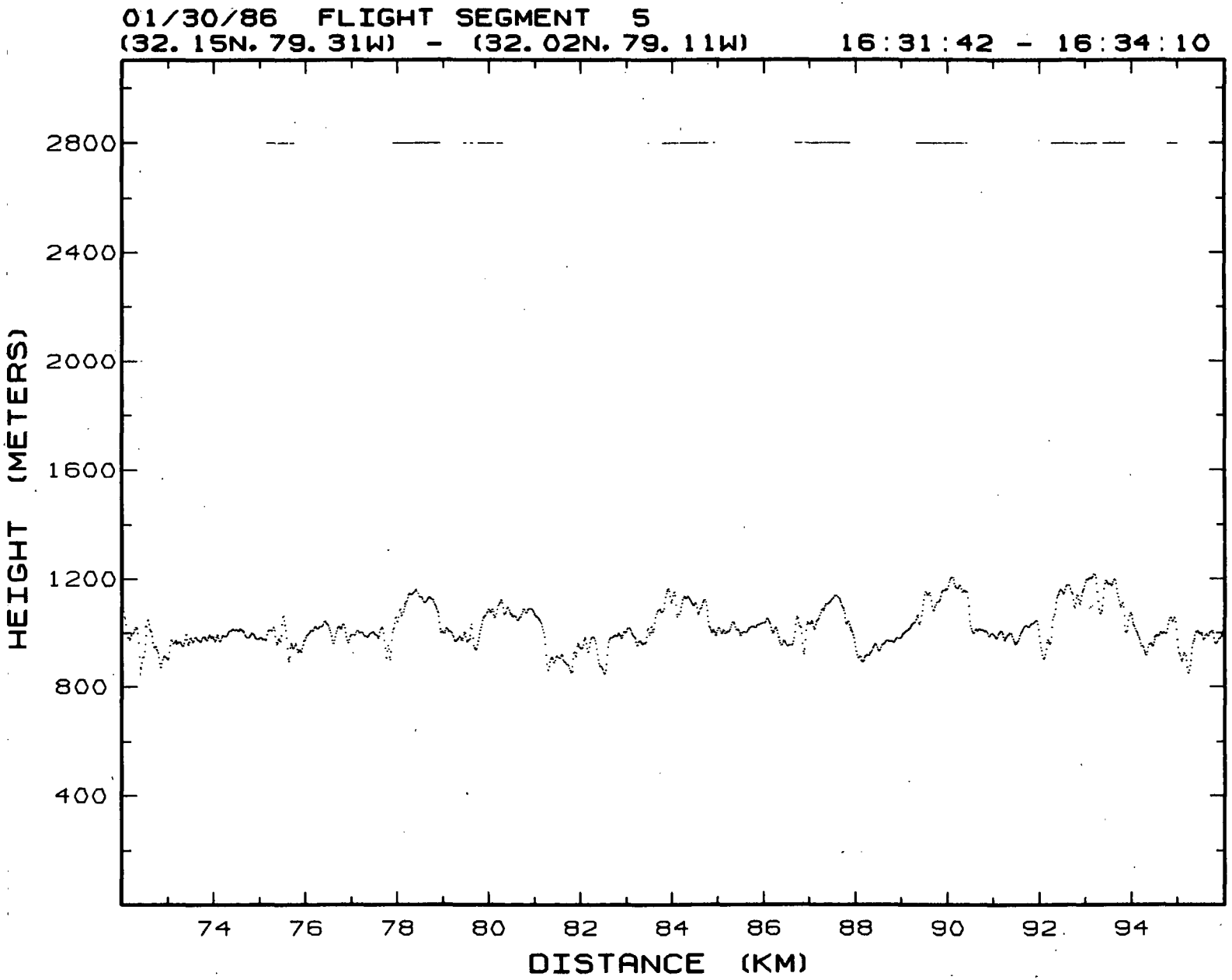

Figure 10.5d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 72-96 km.

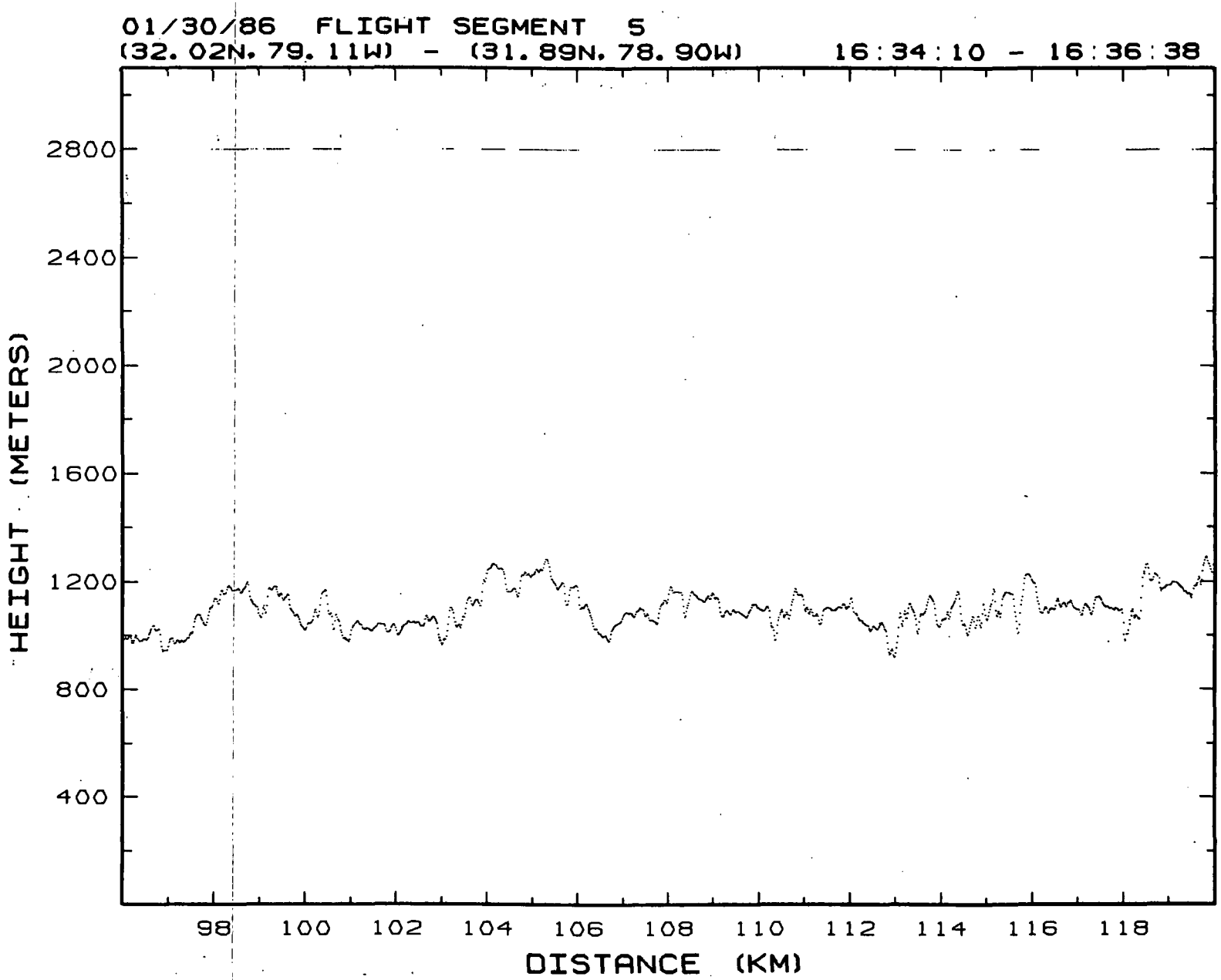

Figure 10.5e. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 96-120 km.

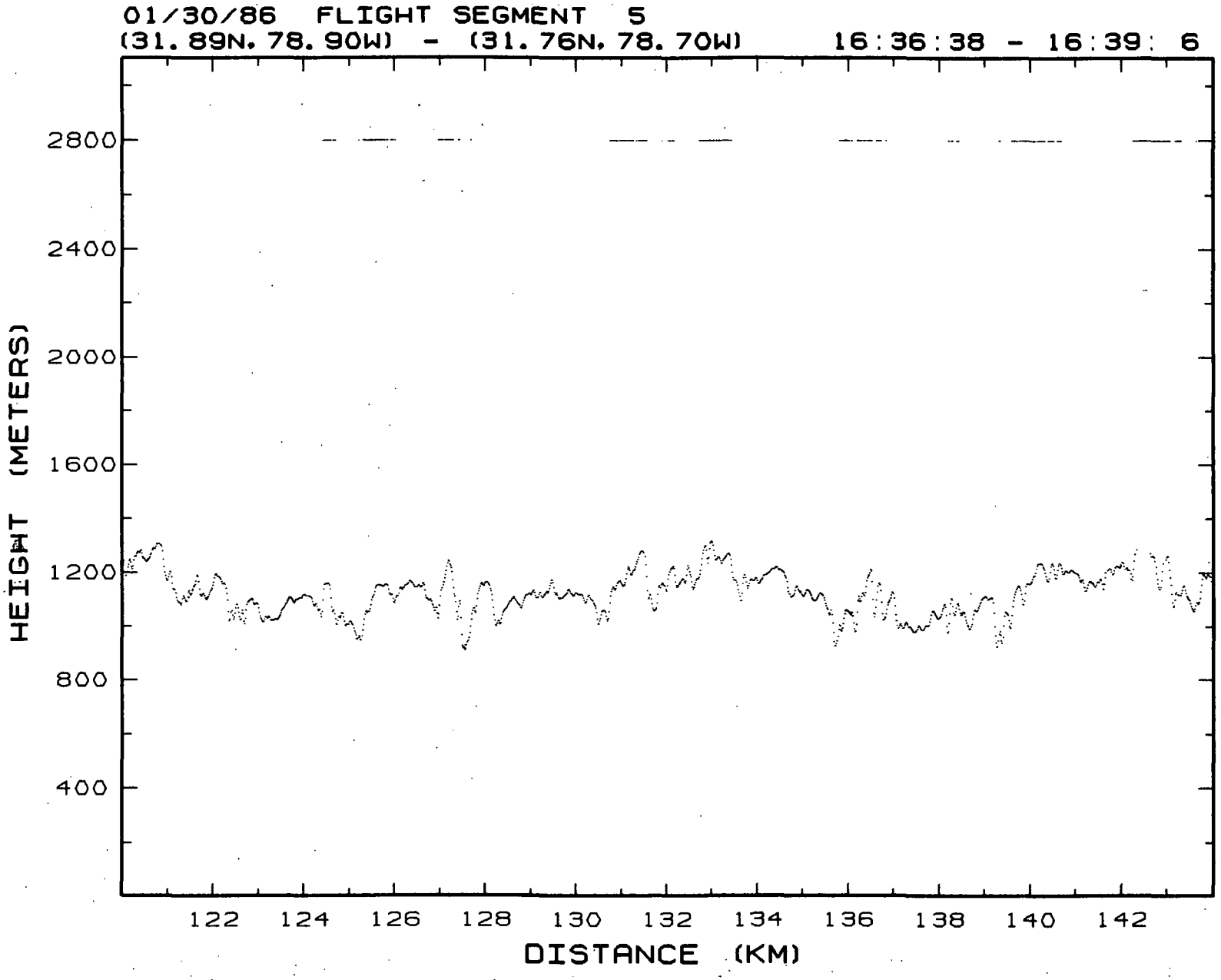

Figure 10.5f. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 120-144 km.

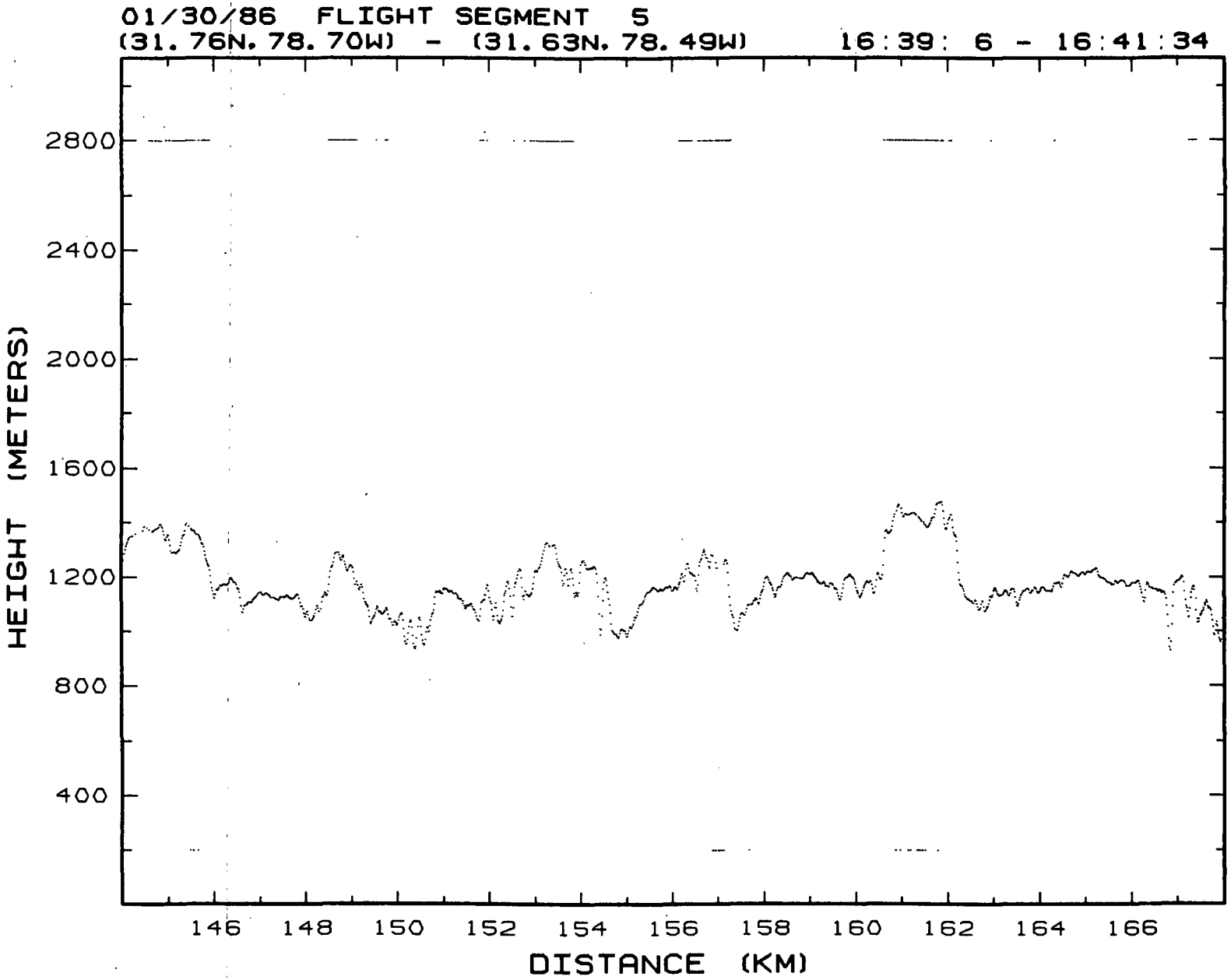

Figure 10.5g. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 144-168 km.

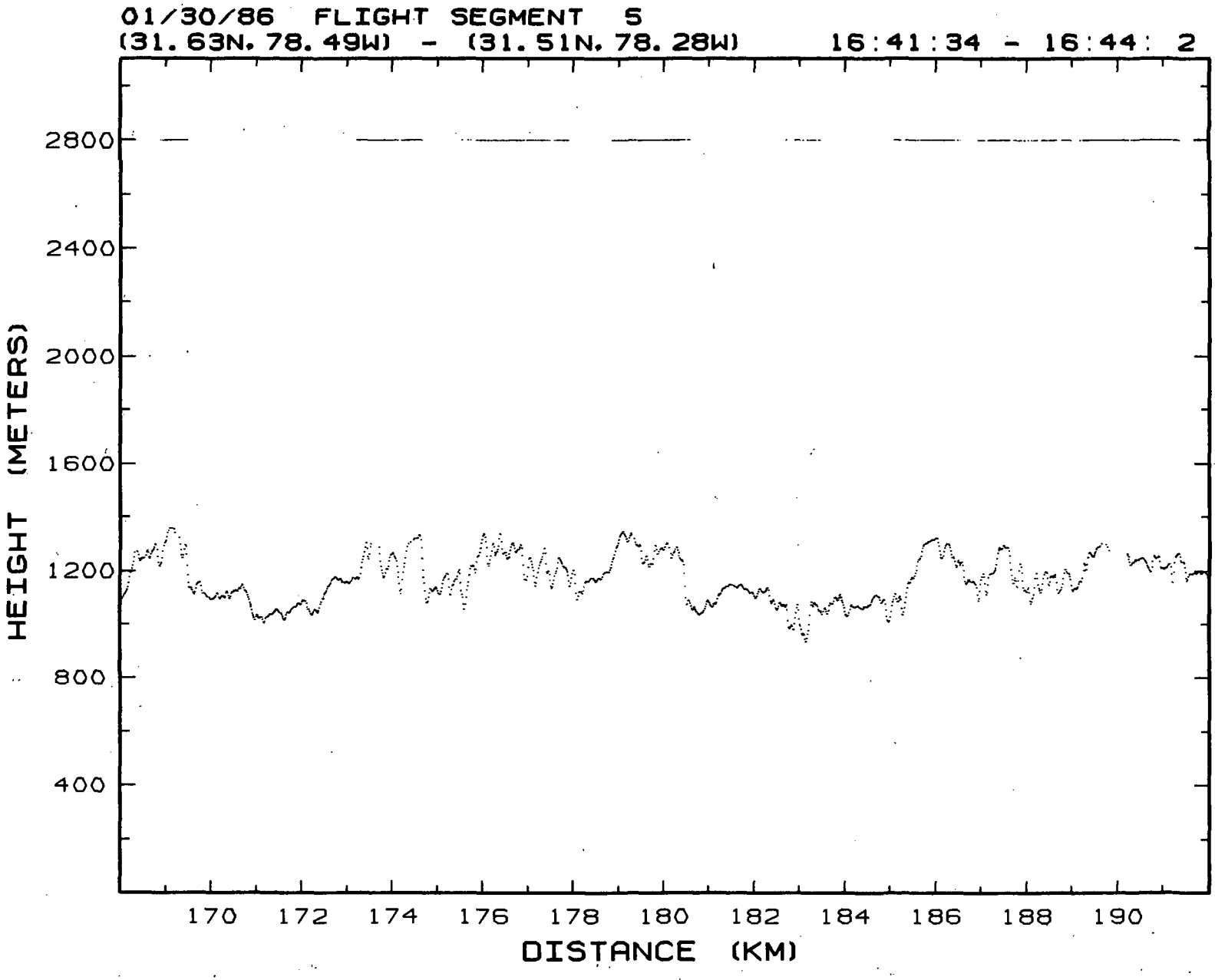

Figure 10.5h. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 168-192 km.

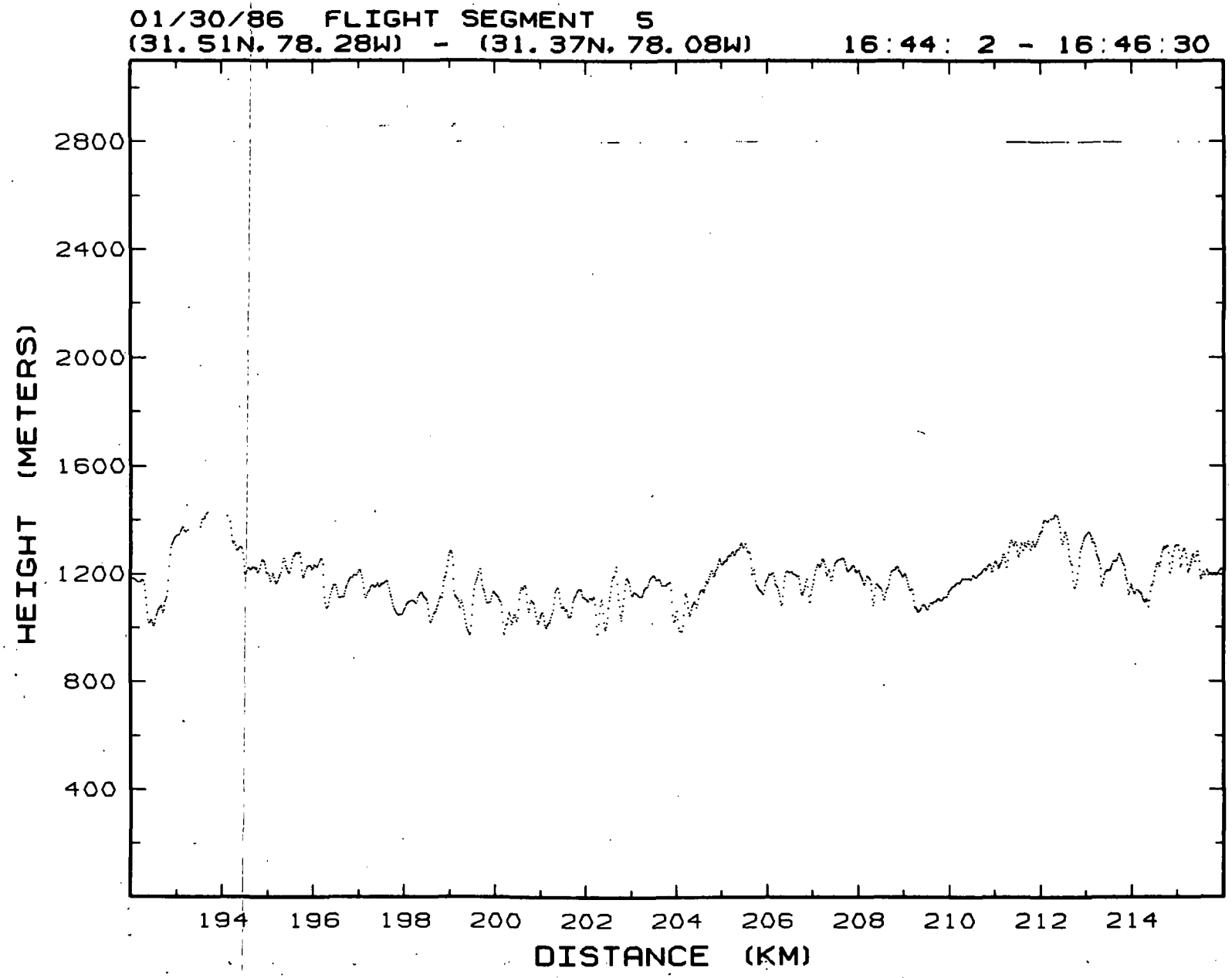

Figure 10.5i. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 192-216 km.

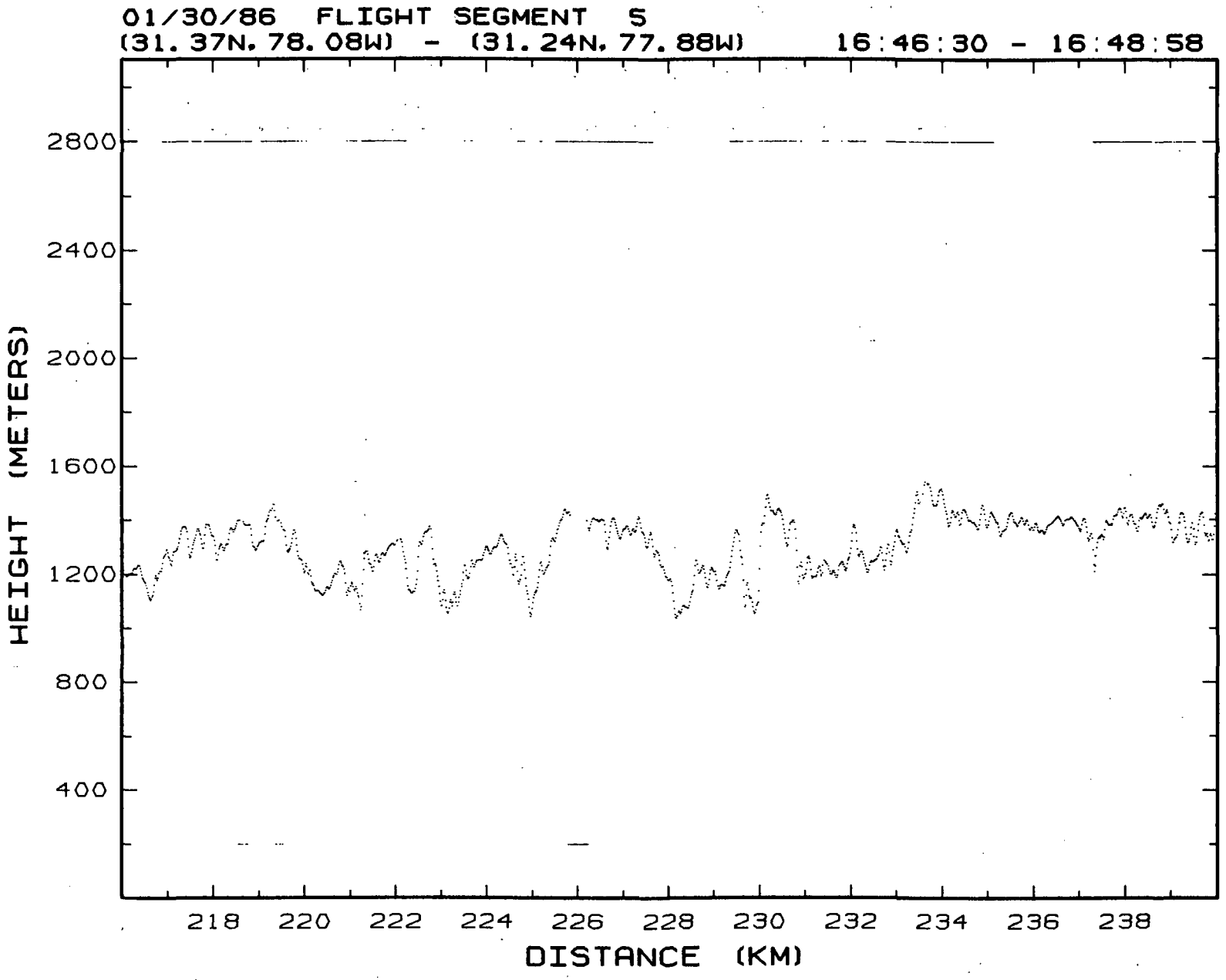

Figure 10.5j. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 216-240 km.

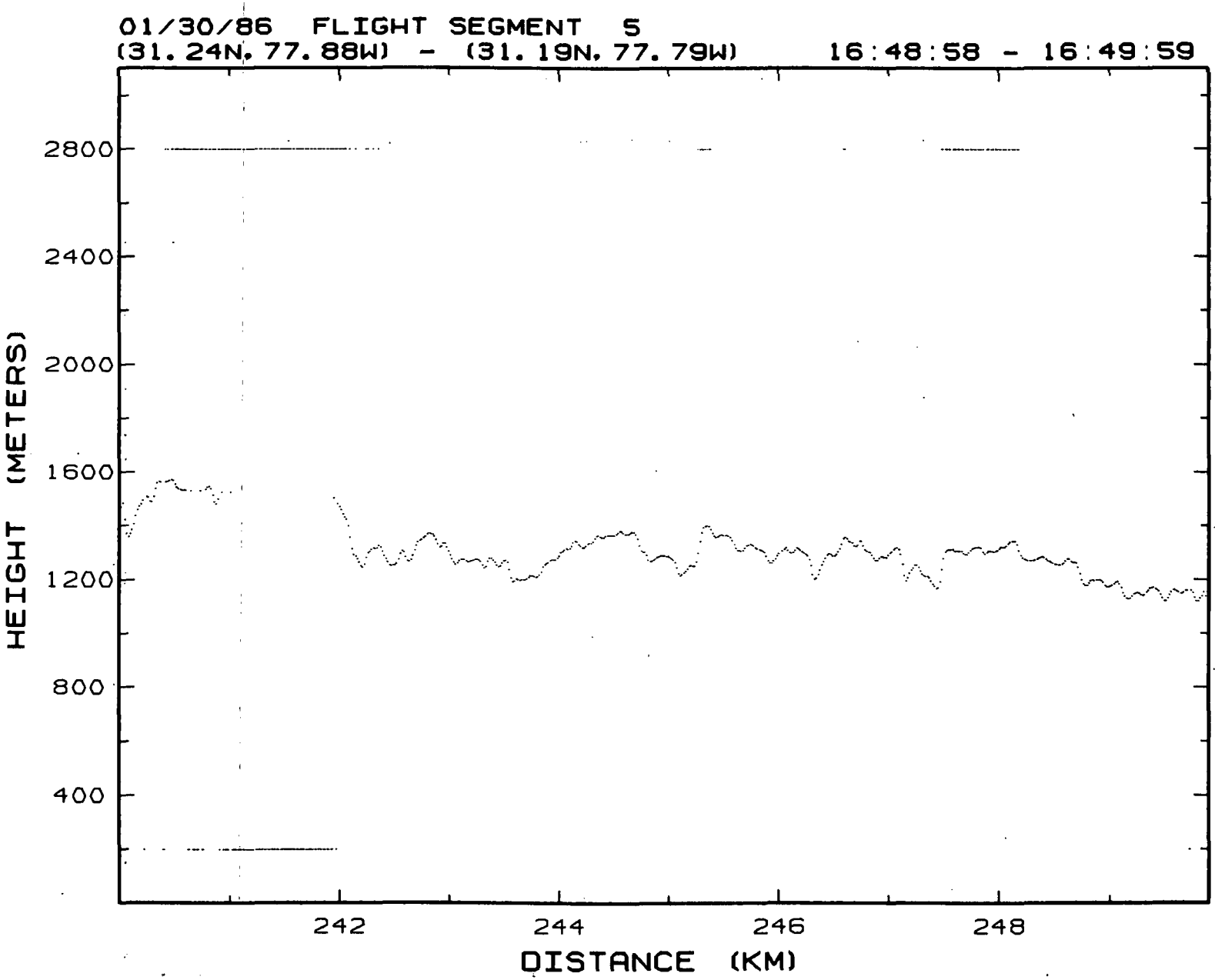

Figure 10.5k. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 5, 240-250 km.

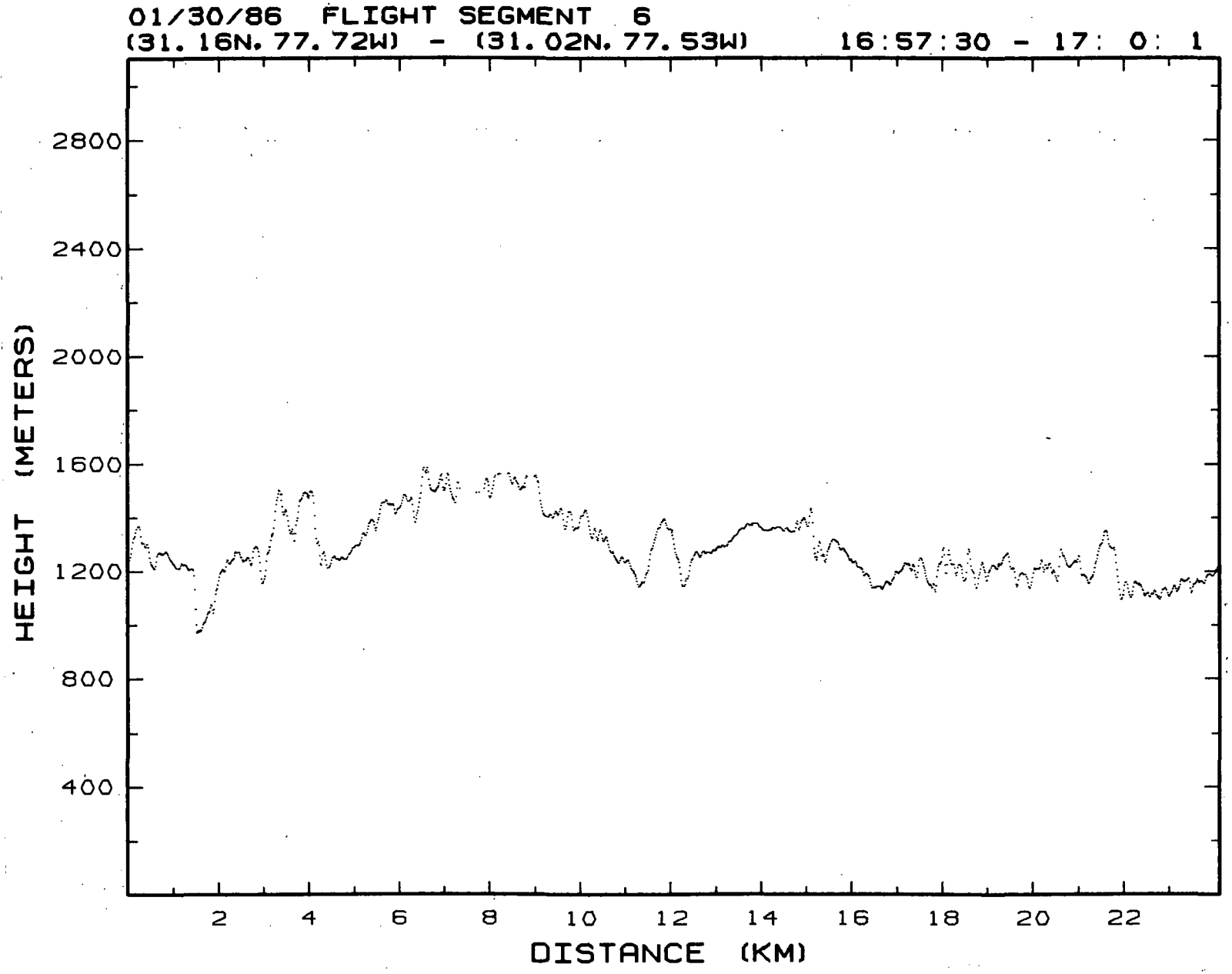

Figure 10.6a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 6, 0-24 km.

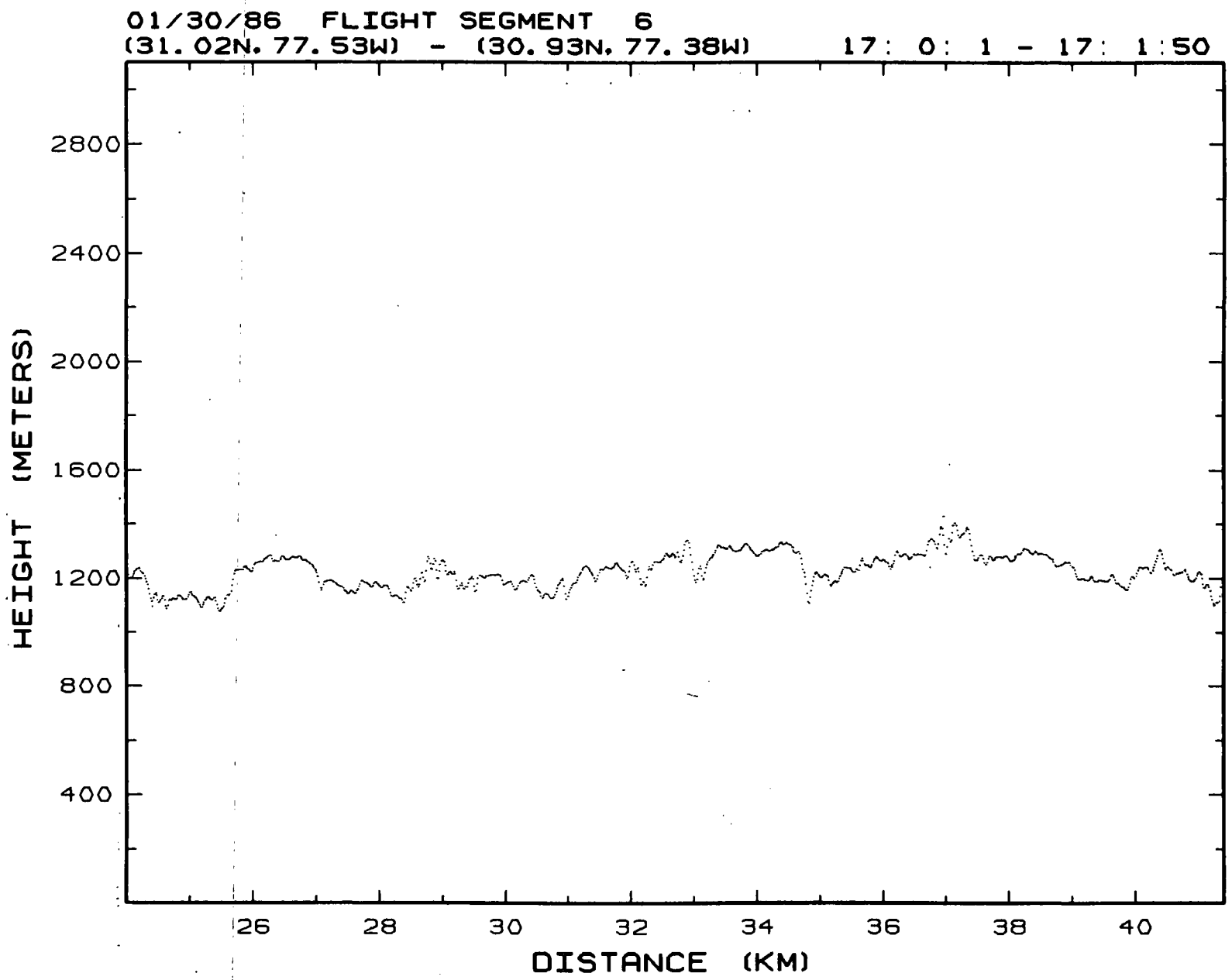

Figure 10.6b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 6, 24-41 km.

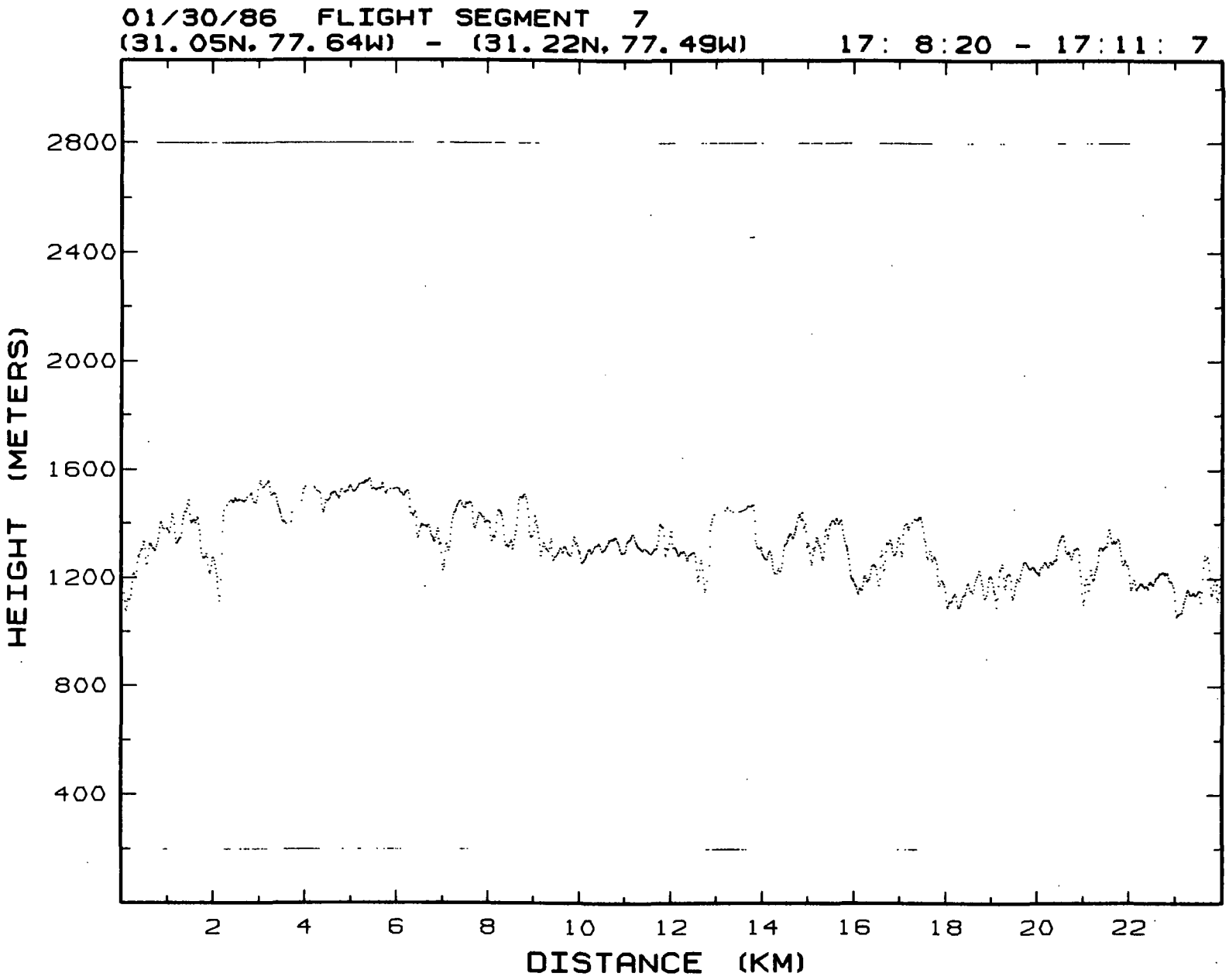

Figure 10.7a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 7, 0-24 km.

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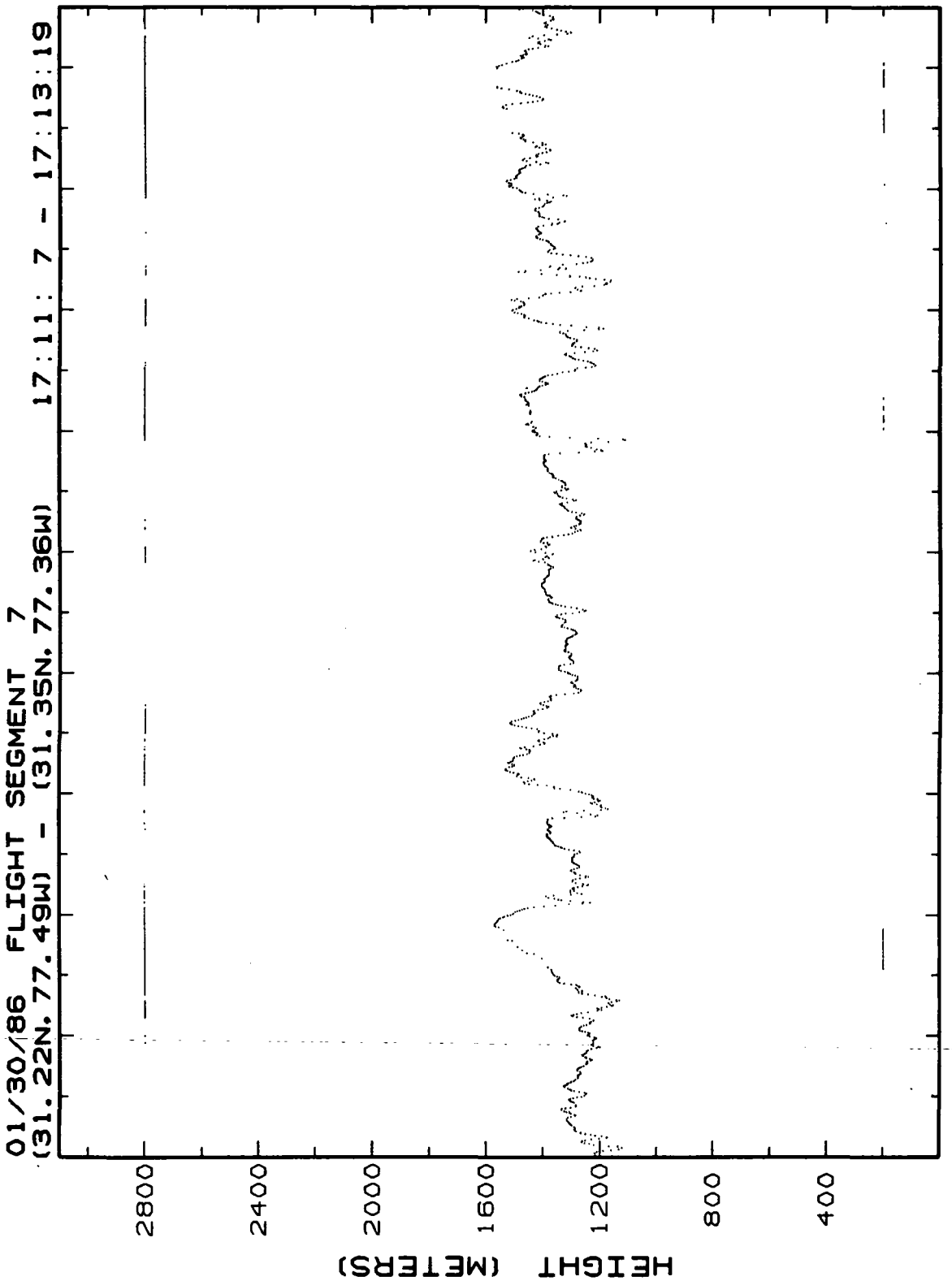

Figure 10.7b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 7, 24-43 km.

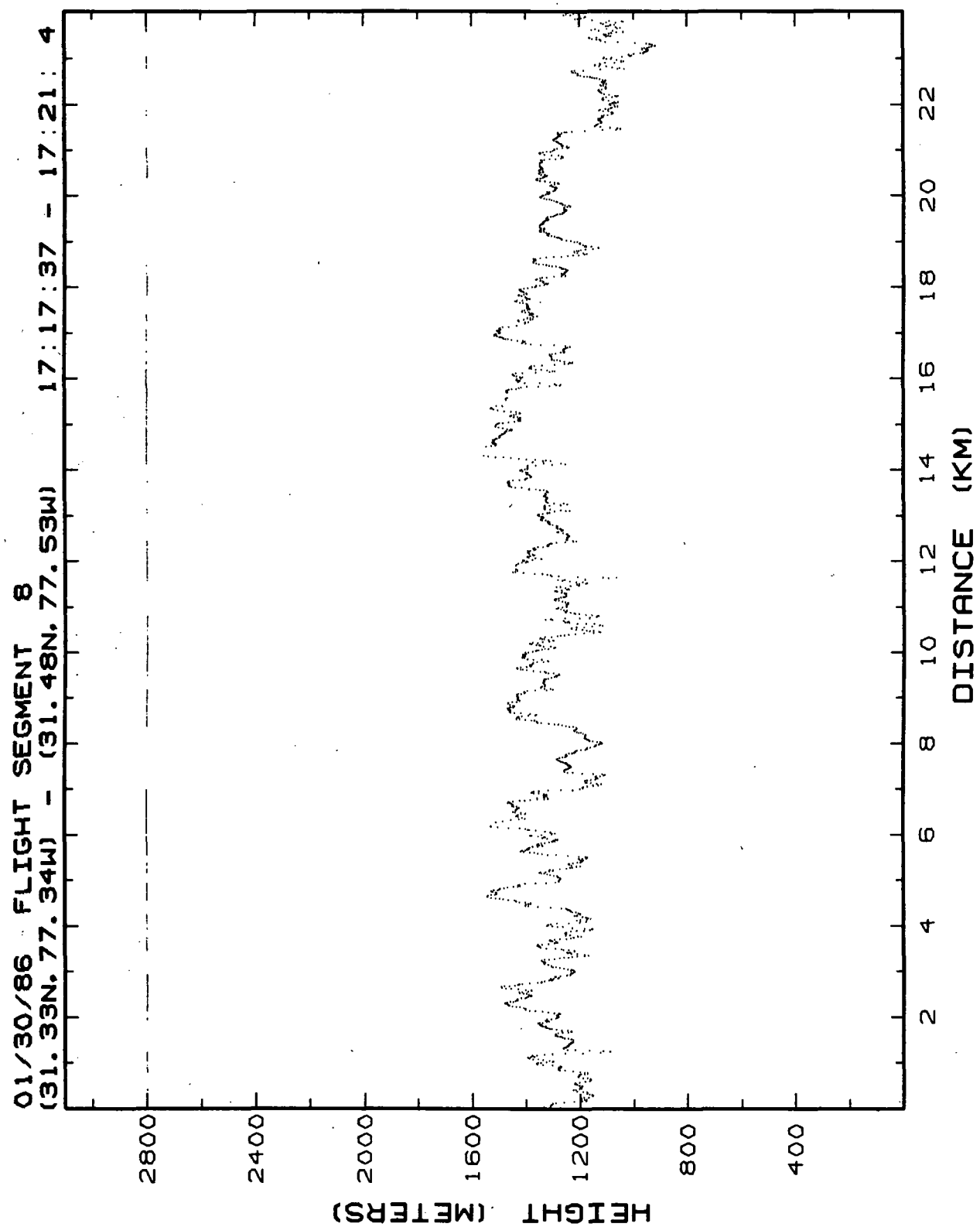

Figure 10.8a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 8, 0-24 km.

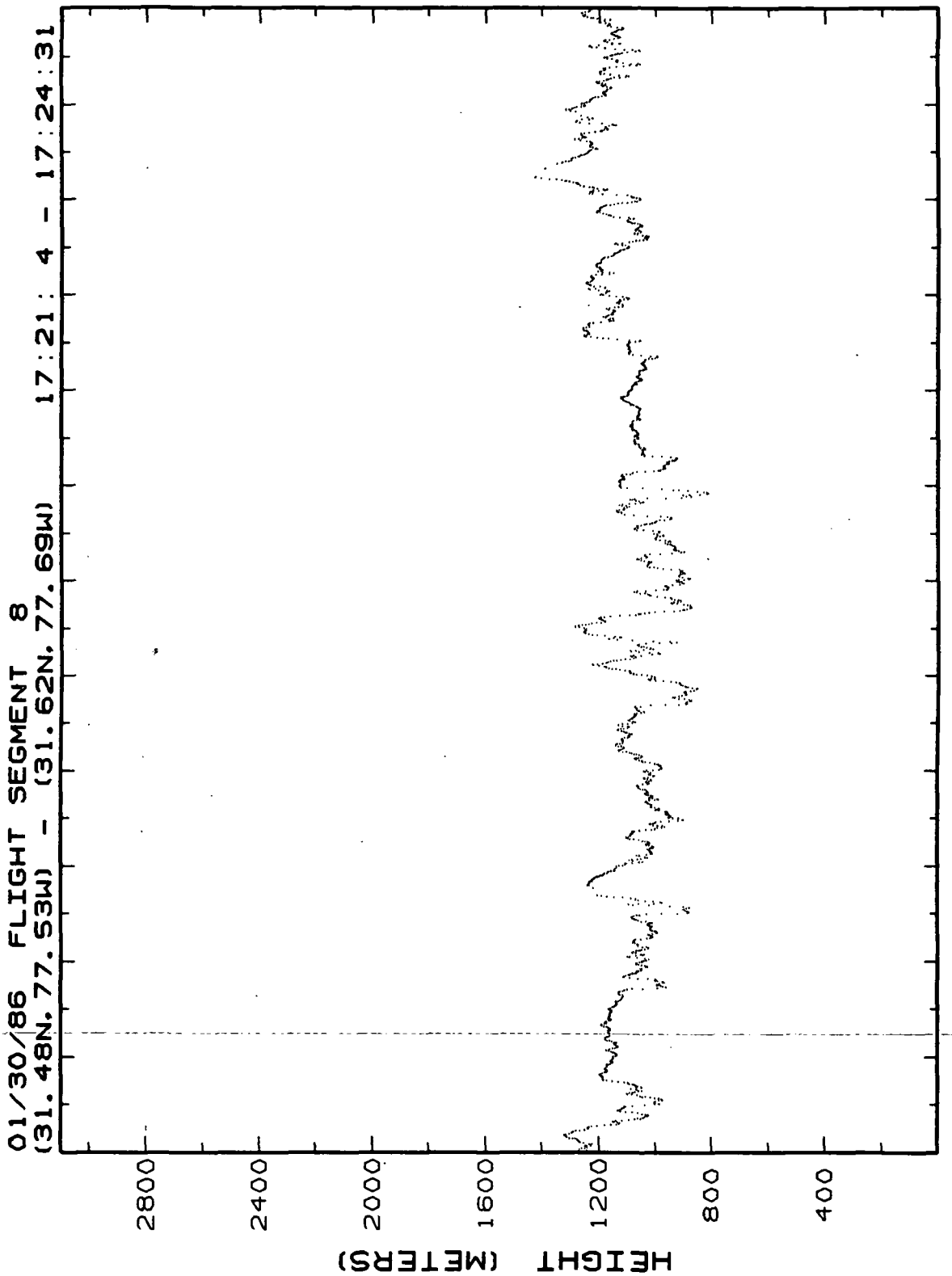

Figure 10.8b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 8, 24-48 km.

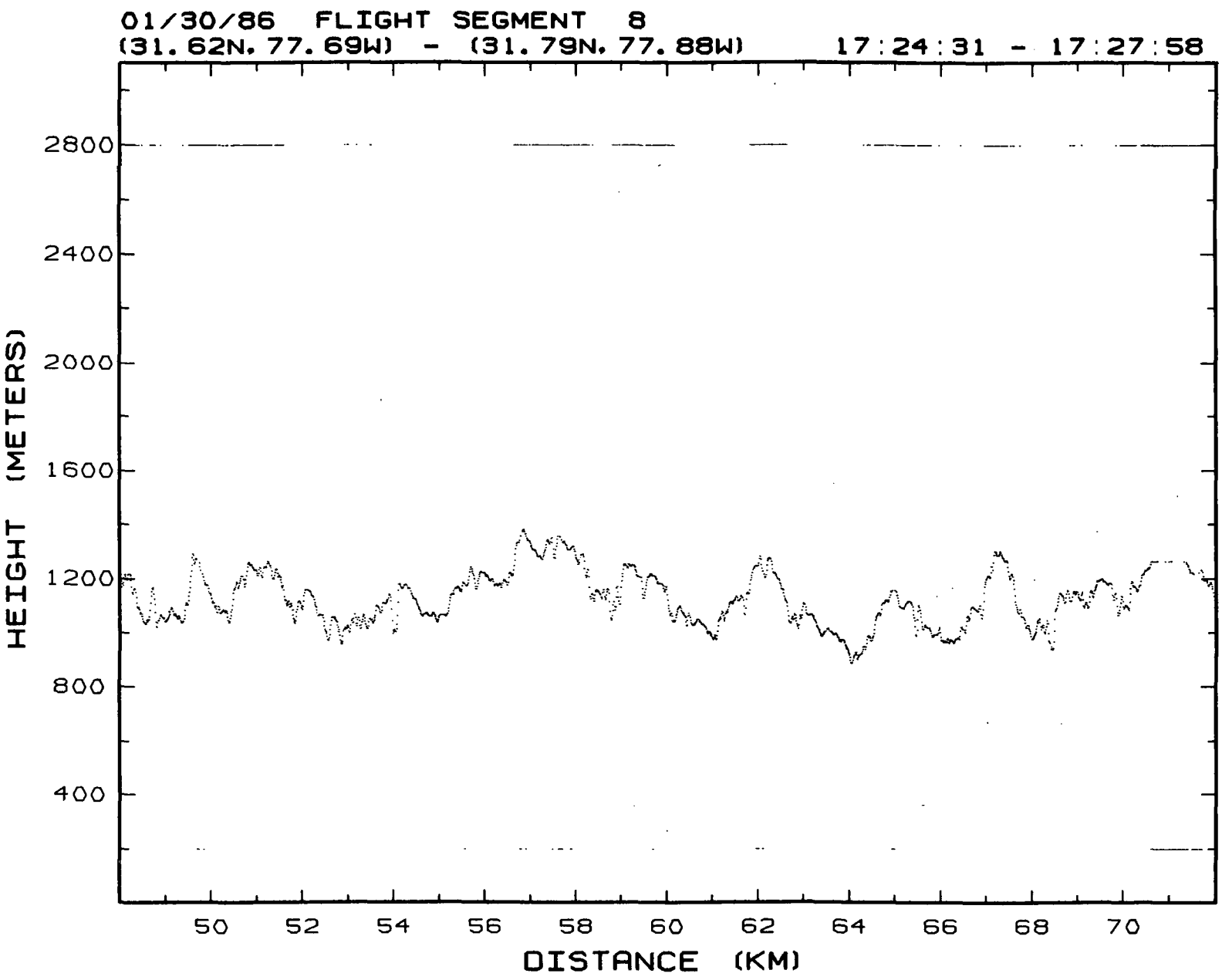

Figure 10.8c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 8, 48-72 km.

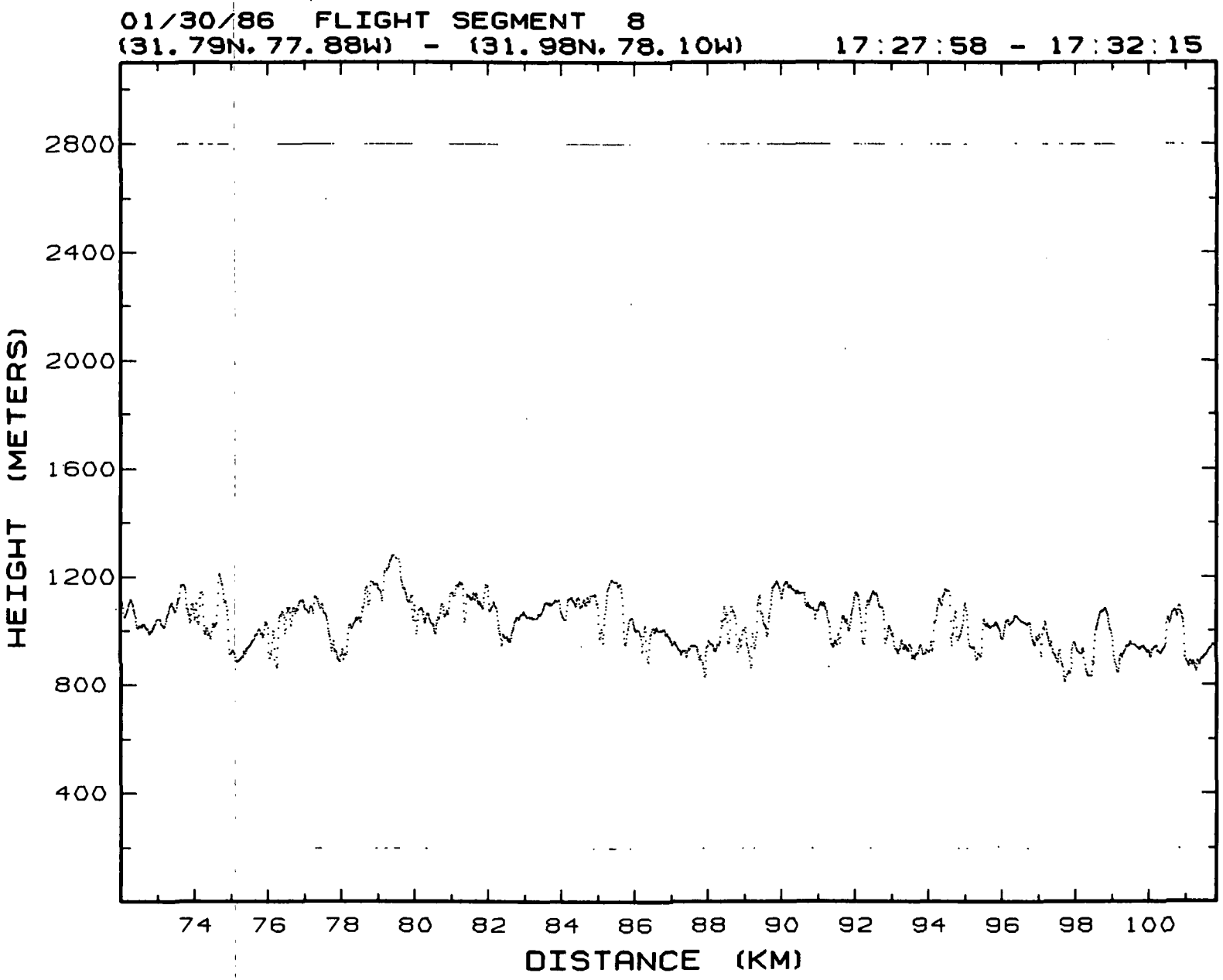

Figure 10.8d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 8, 72-102 km.

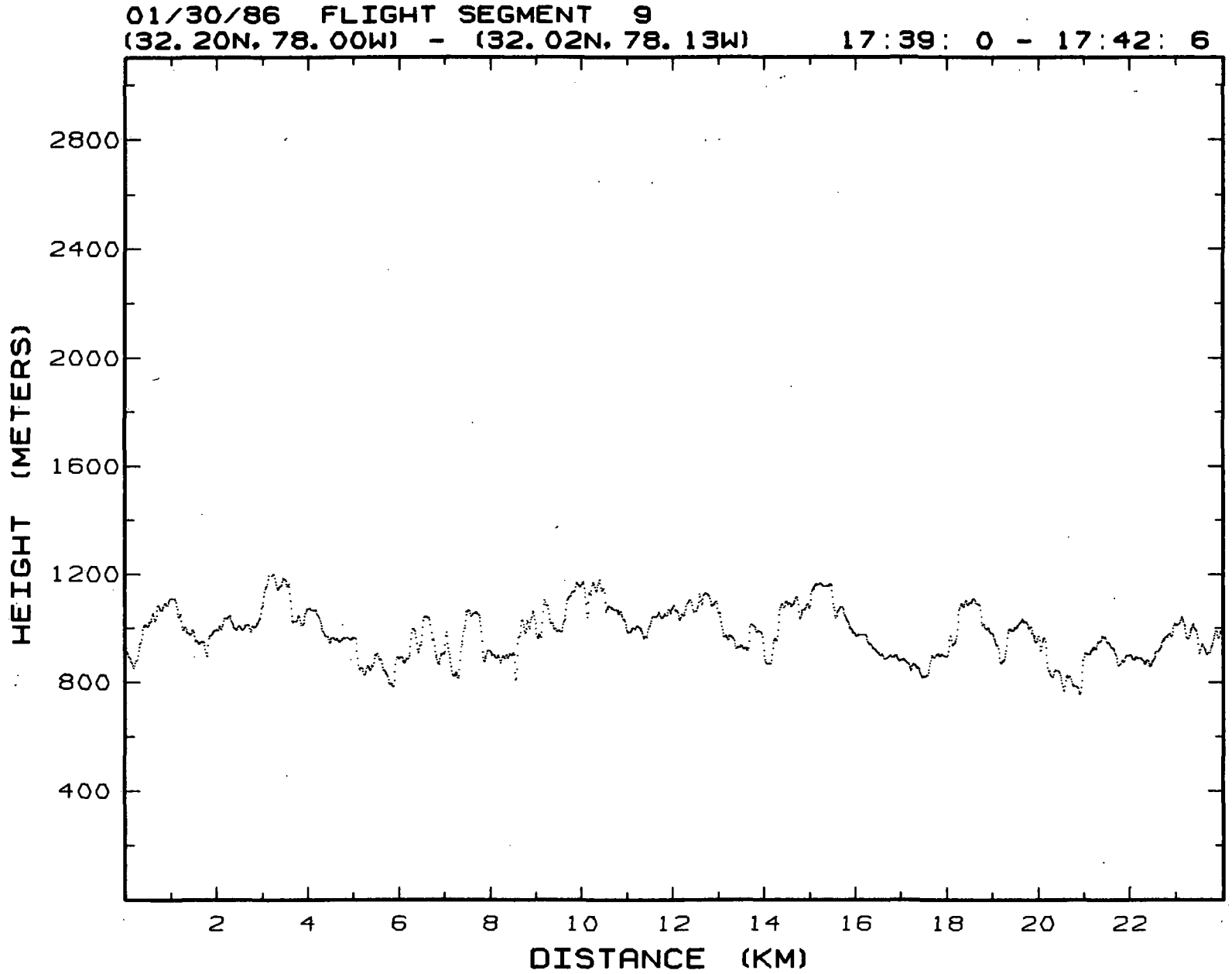

Figure 10.9a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 9, 0-24 km.

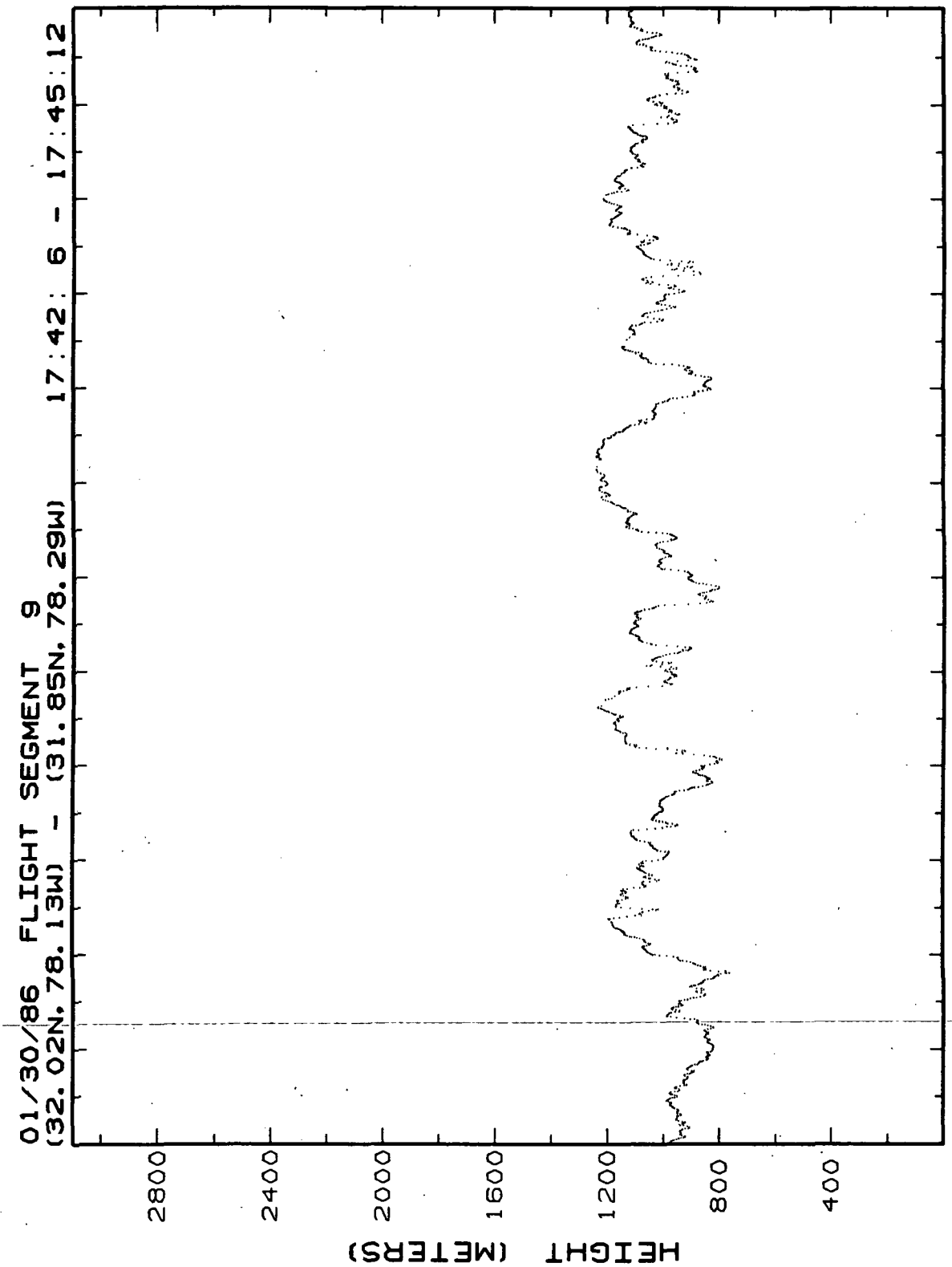

Figure 10.9b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 9, 24-48 km.

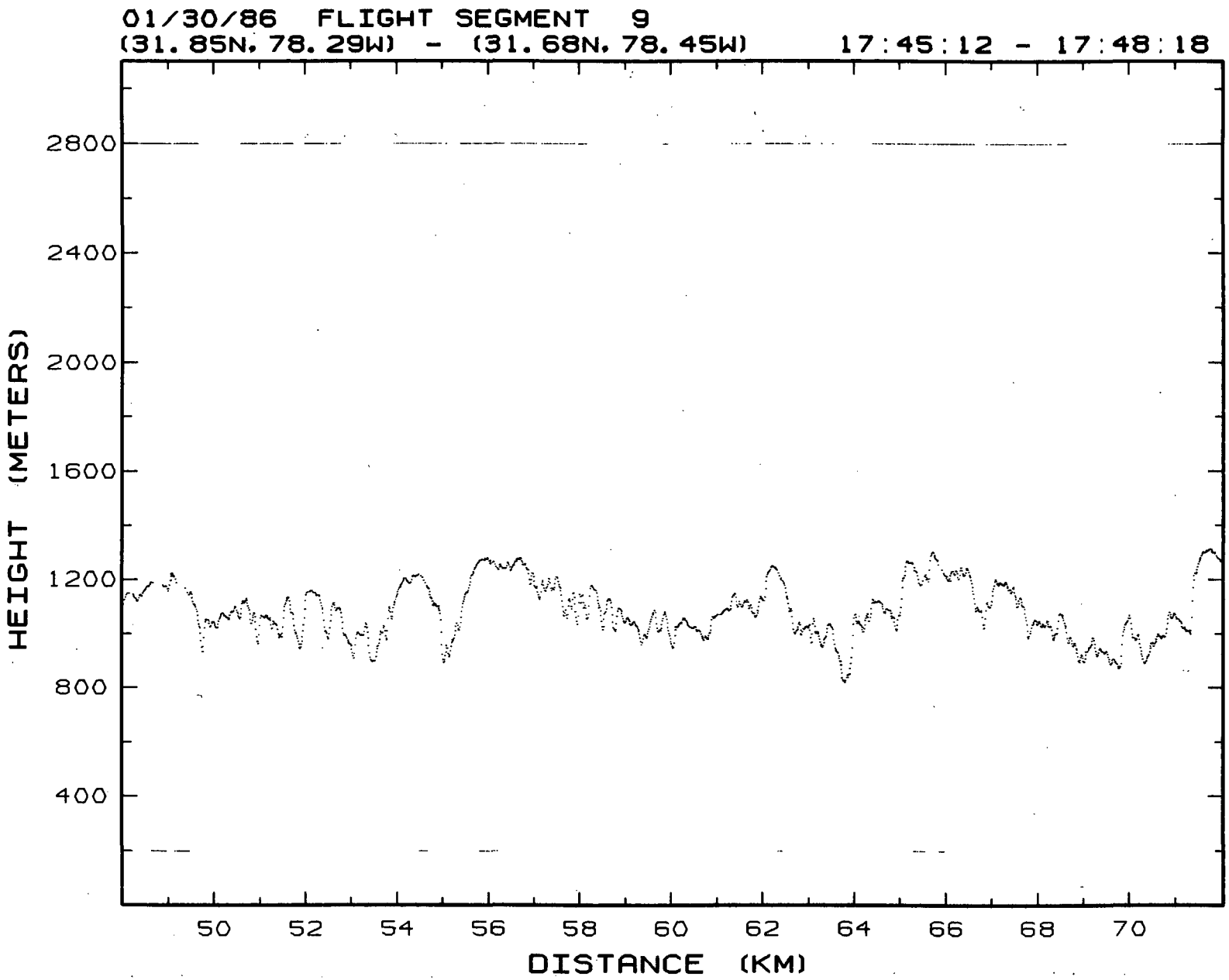

Figure 10.9c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 9, 48-72 km.

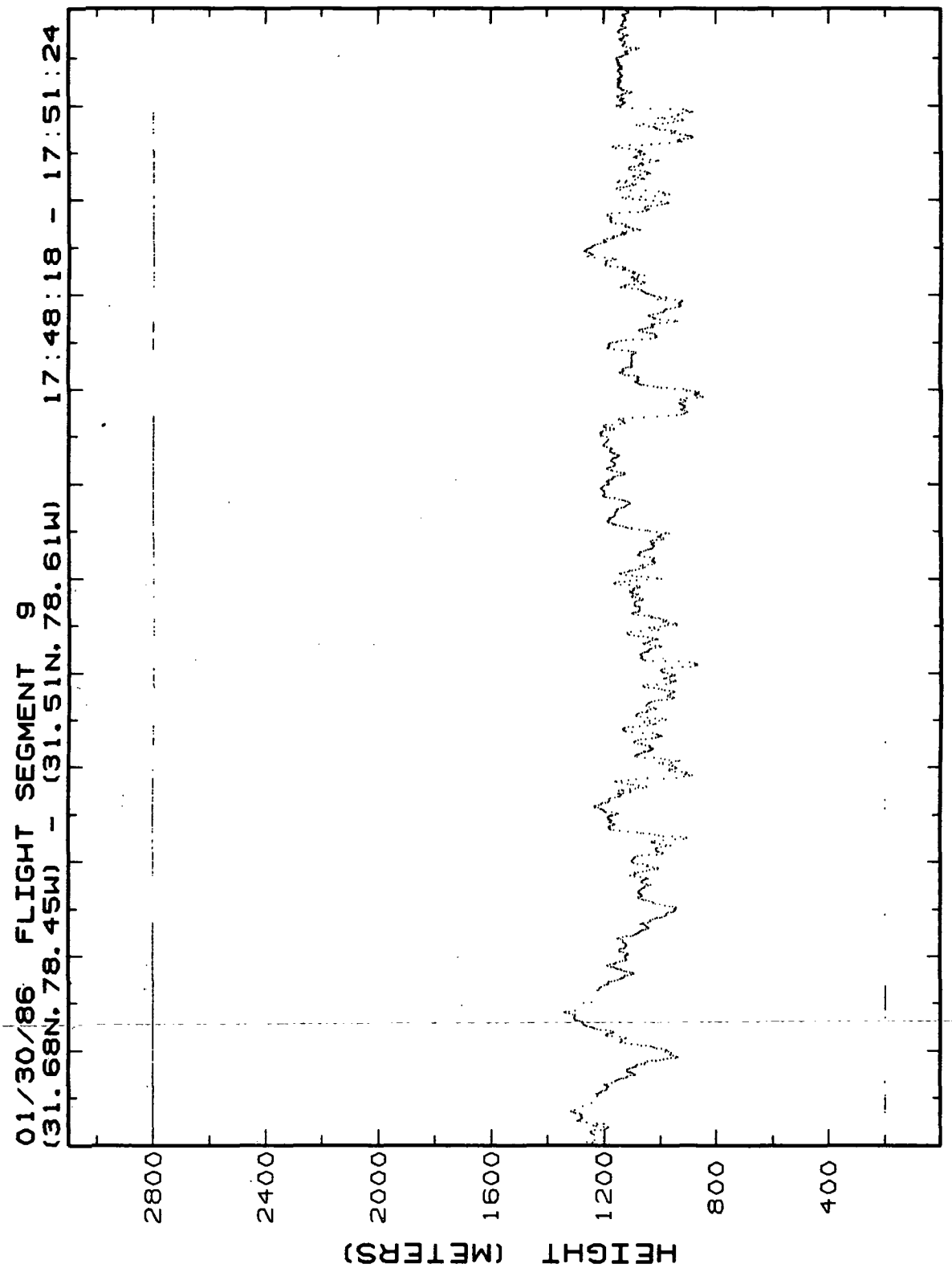

Figure 10.9d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 9, 72-96 km.

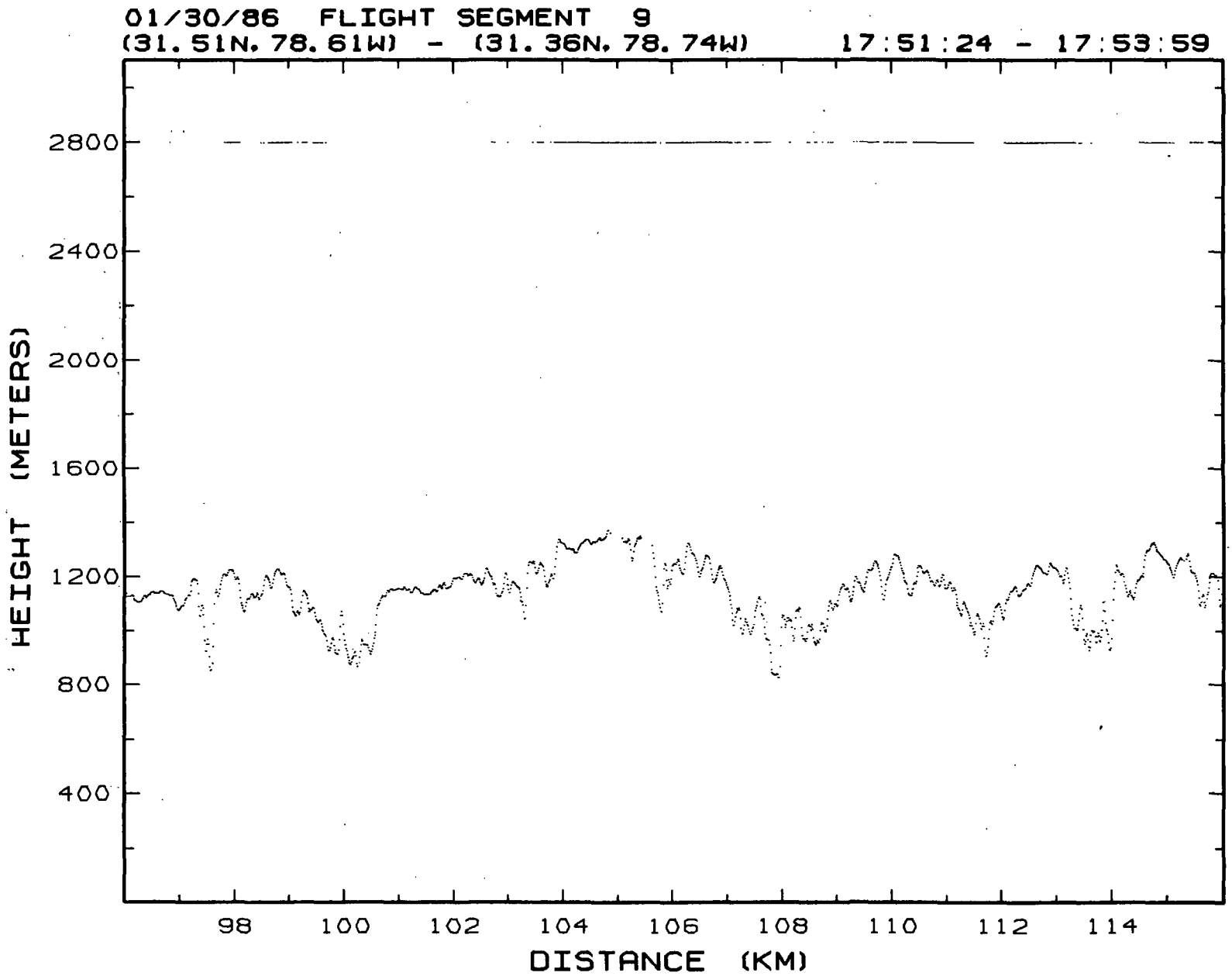

Figure 10.9e. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 9, 96-116 km.

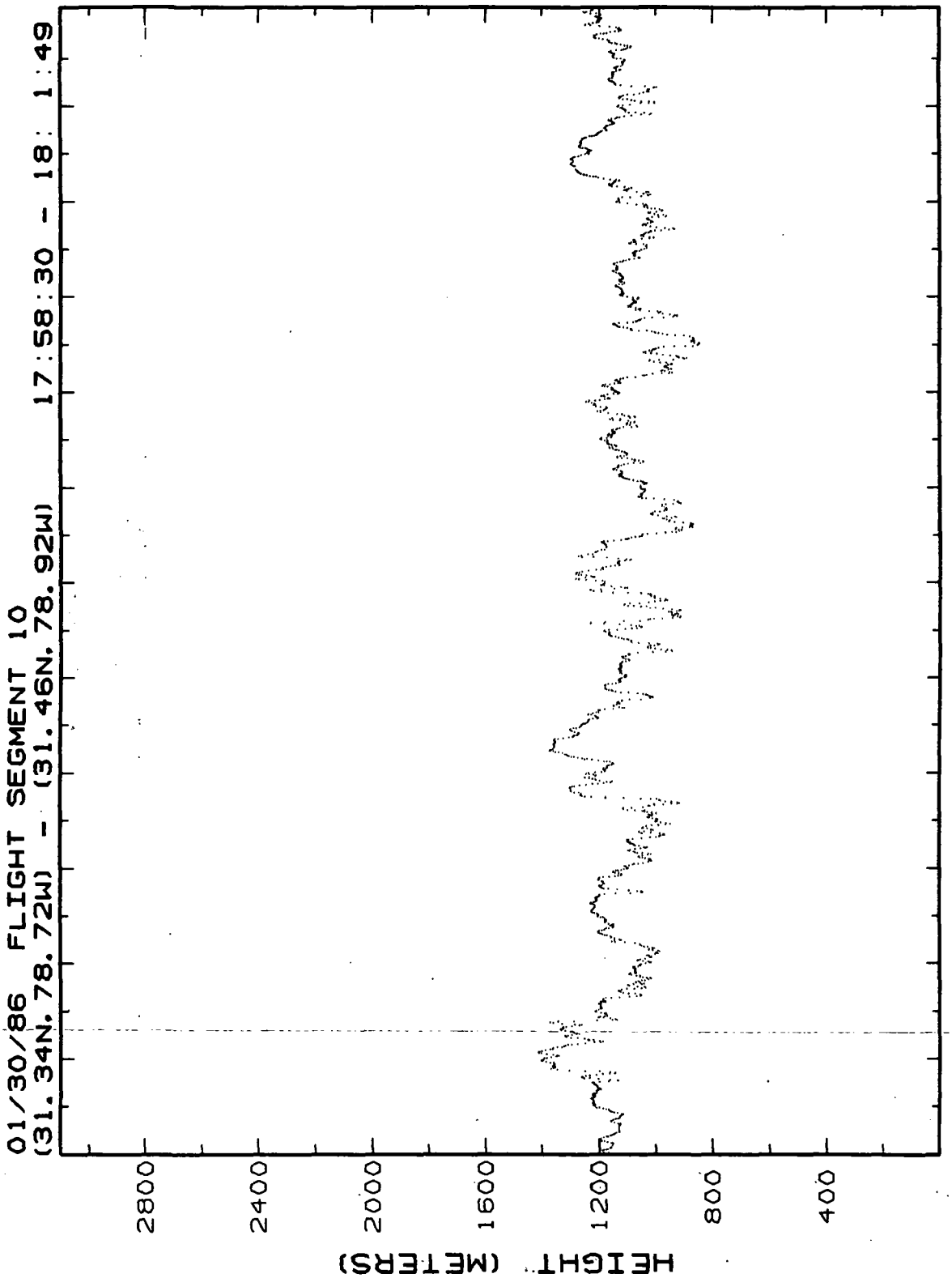

Figure 10.10a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 10, 0-24 km.

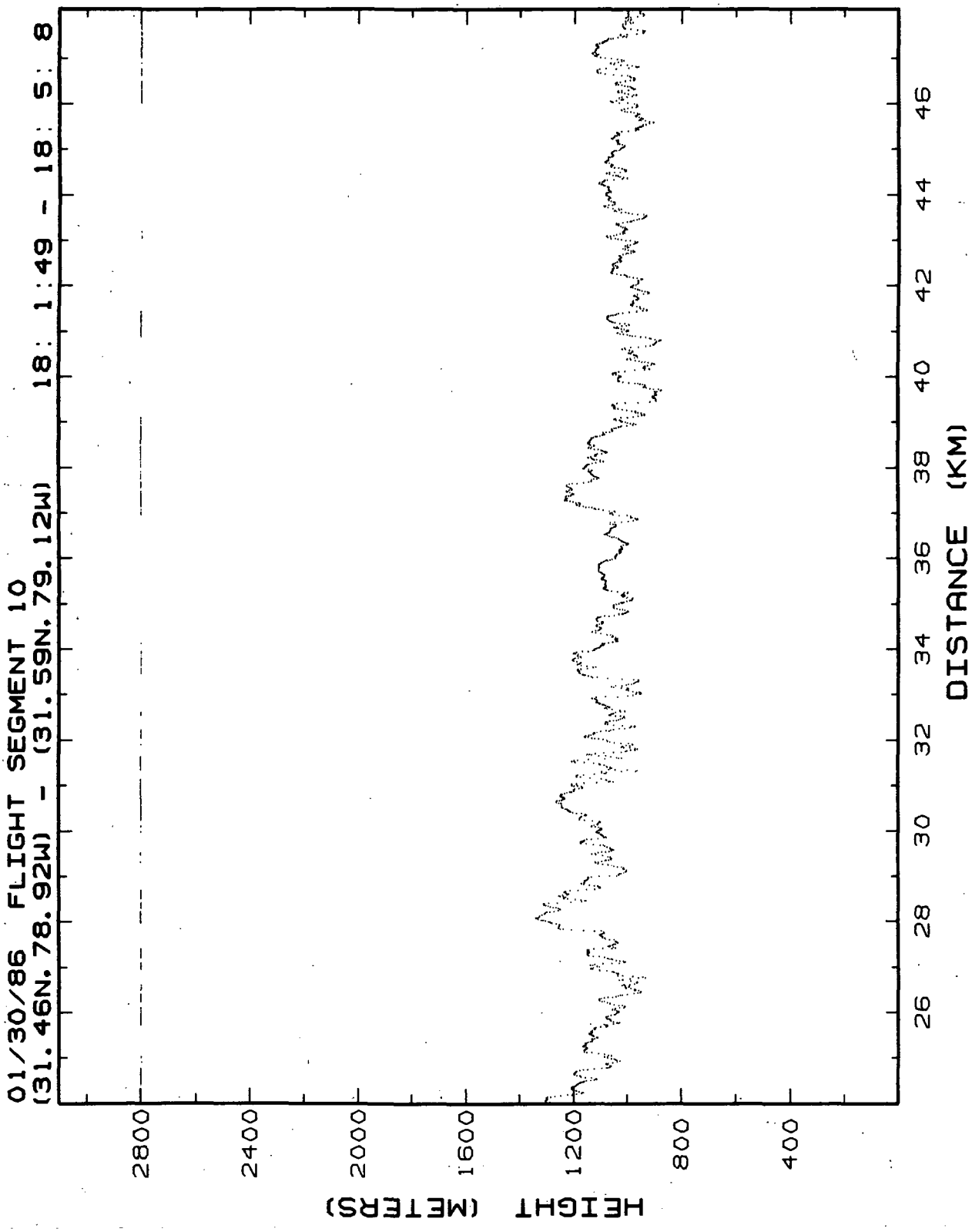

Figure 10.10b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 10, 24-48 km.

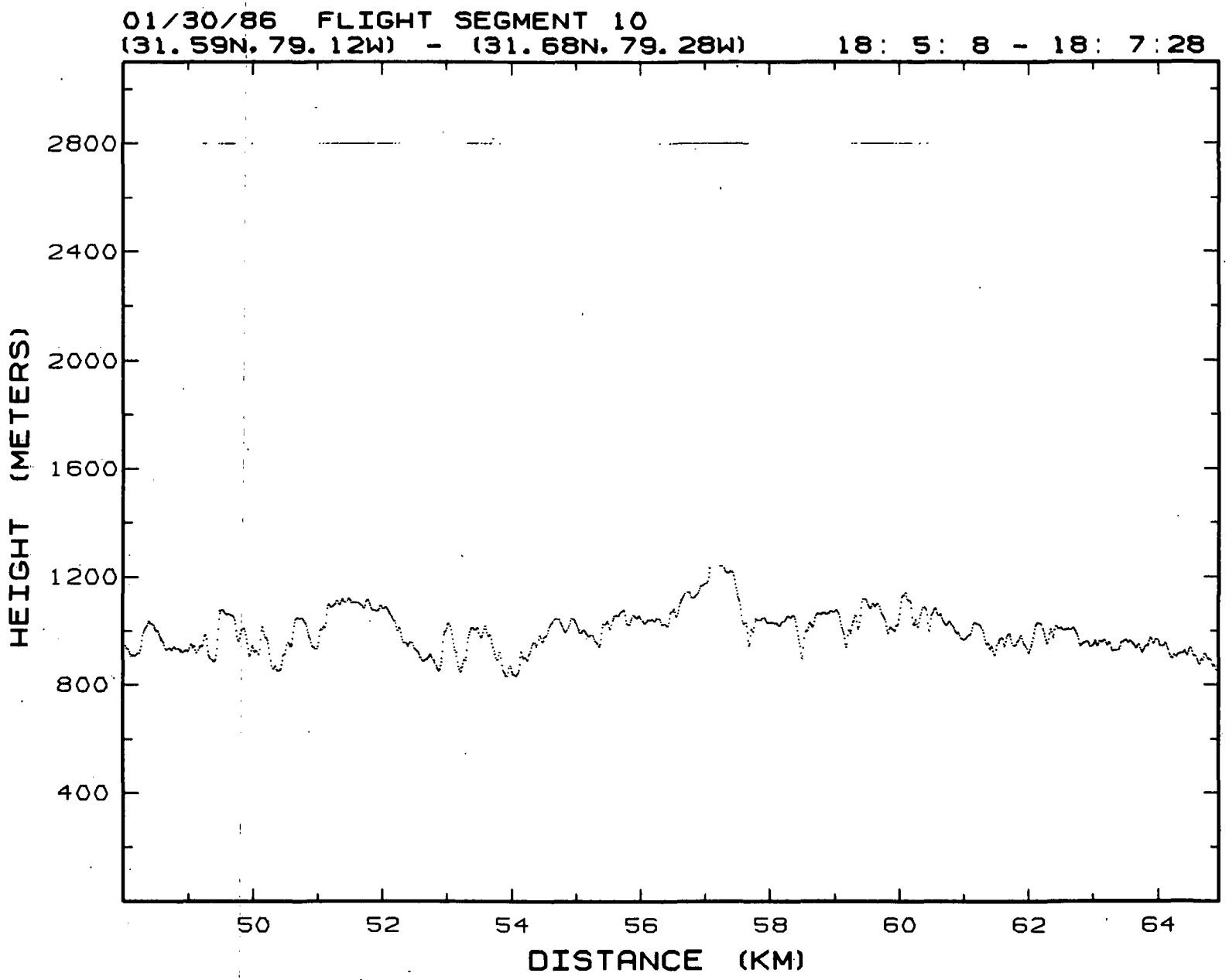

Figure 10.10c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 10, 48-65 km.

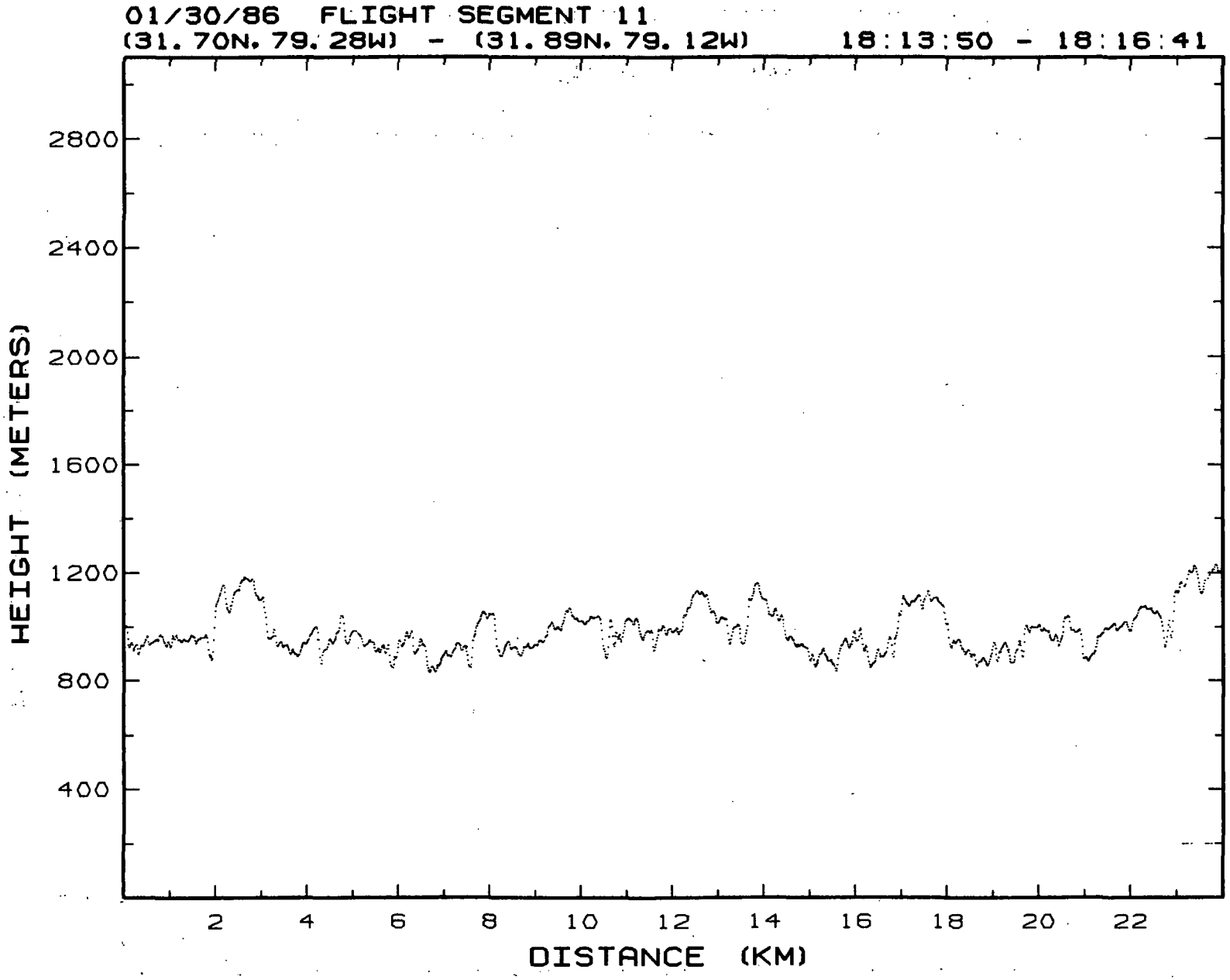

Figure 10.11a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 11, 0-24 km.

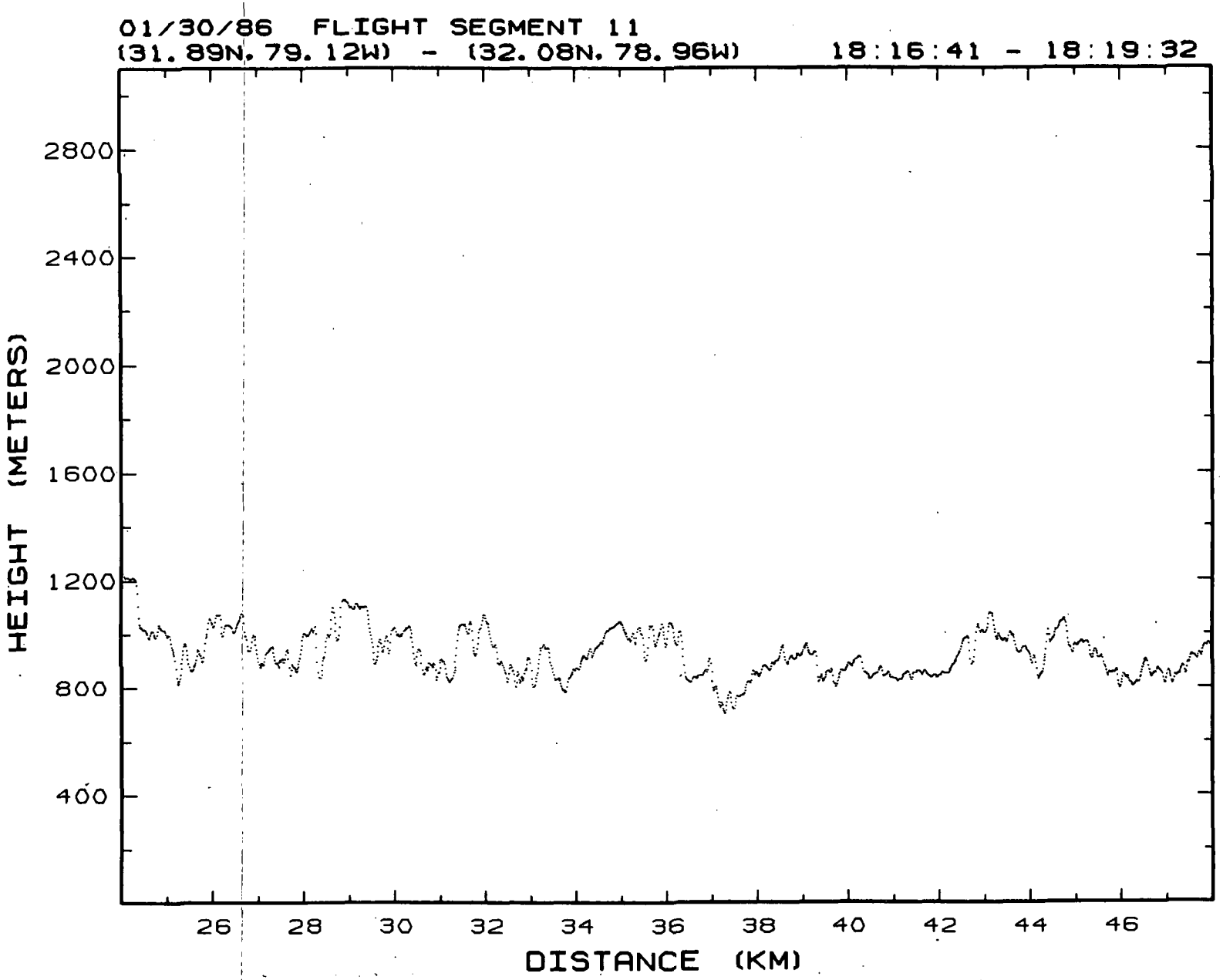

Figure 10.11b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 11, 24-48 km.

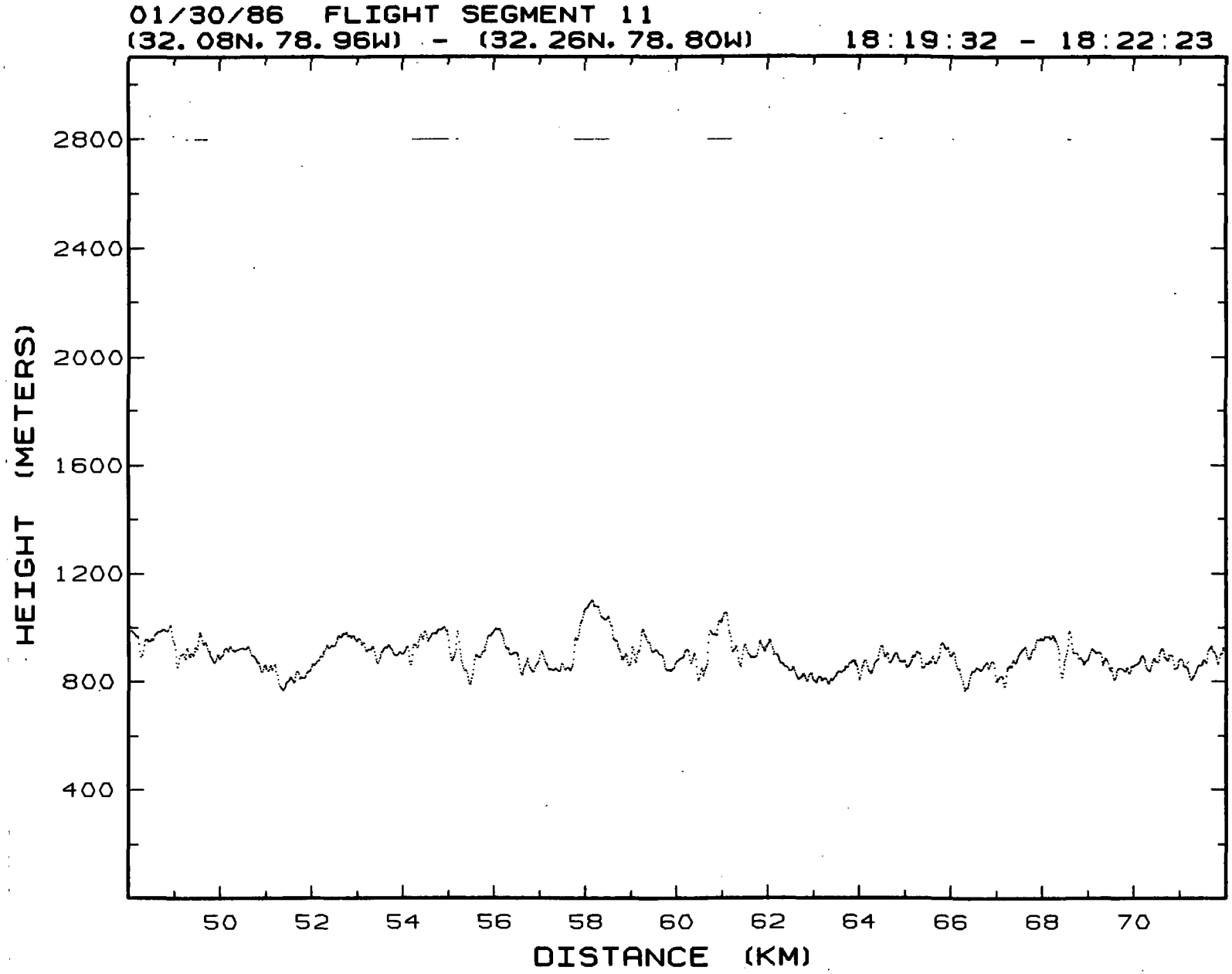

Figure 10.11c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 11, 48-72 km.

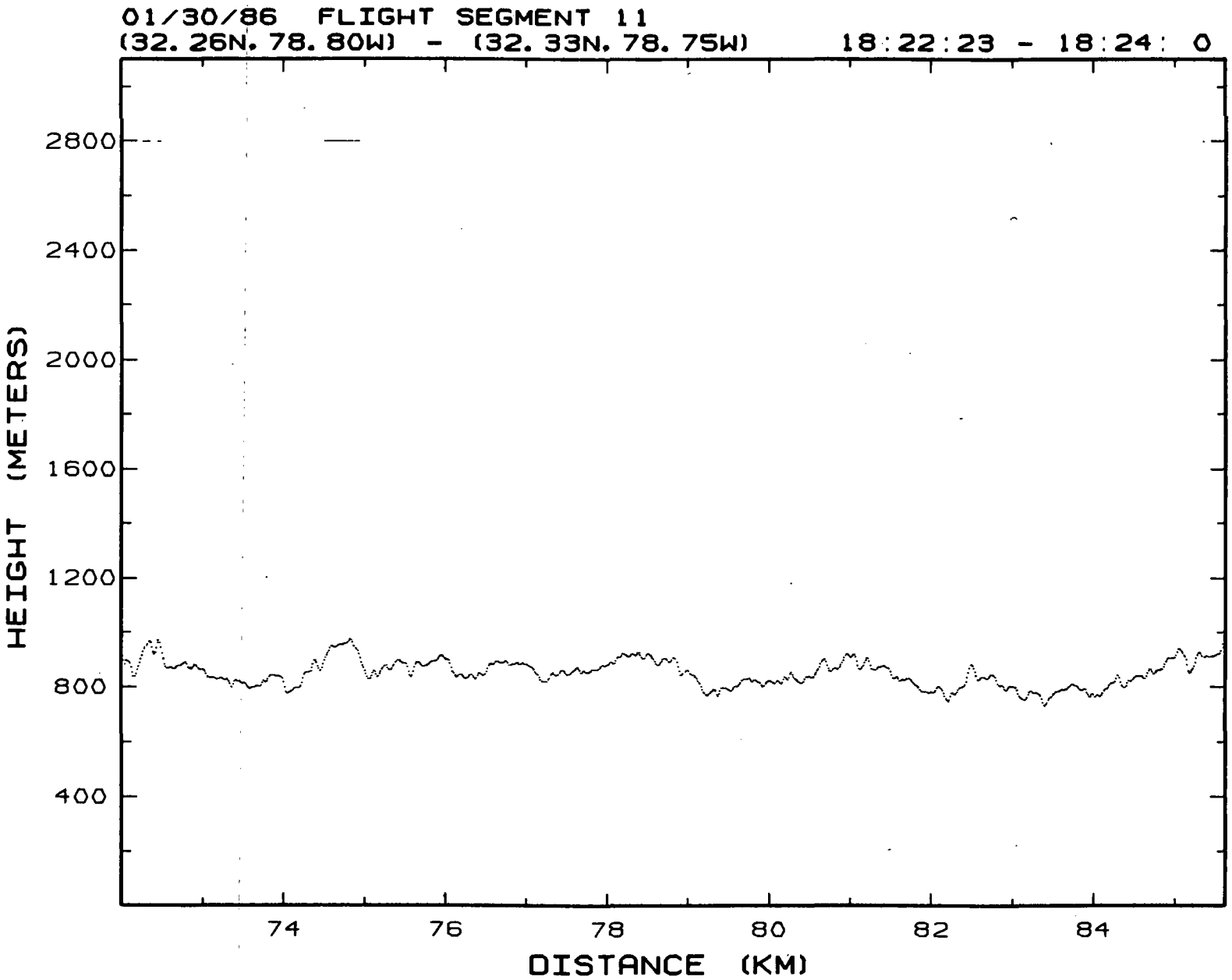

Figure 10.11d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 11, 72-85 km.

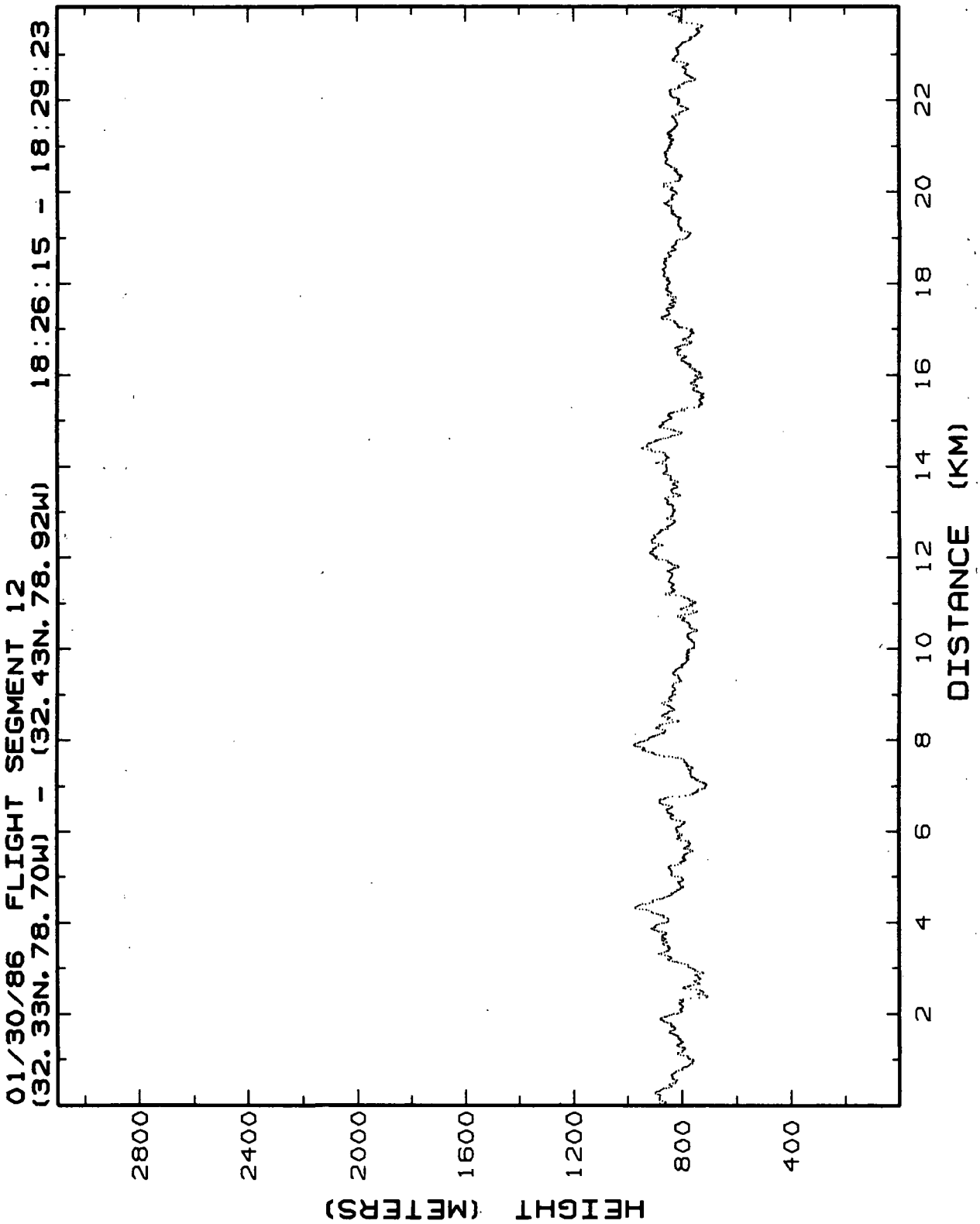

Figure 10.12a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 12, 0-24 km.

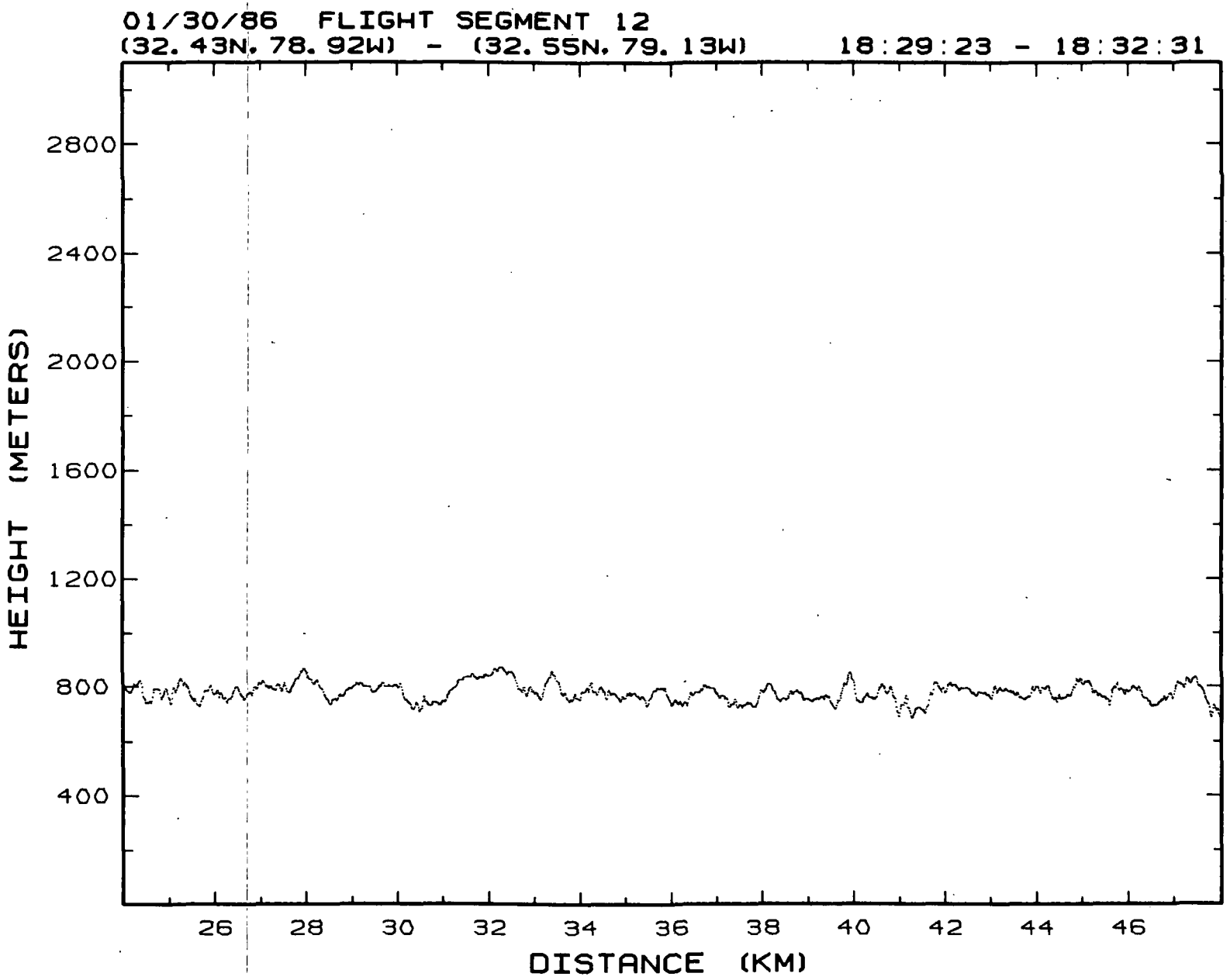

Figure 10.12b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 12, 24-48 km.

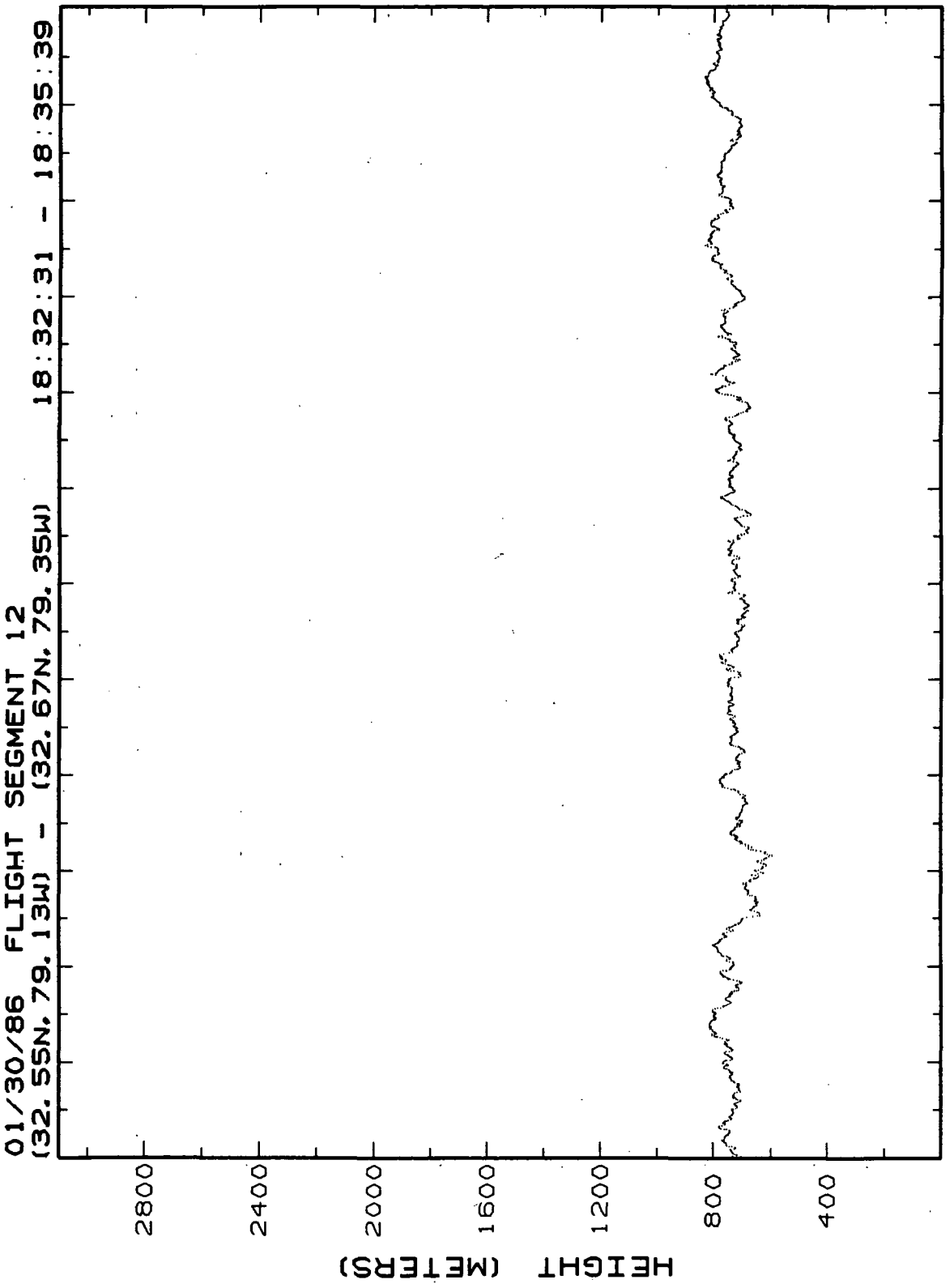

Figure 10.12c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 12, 48-72 km.

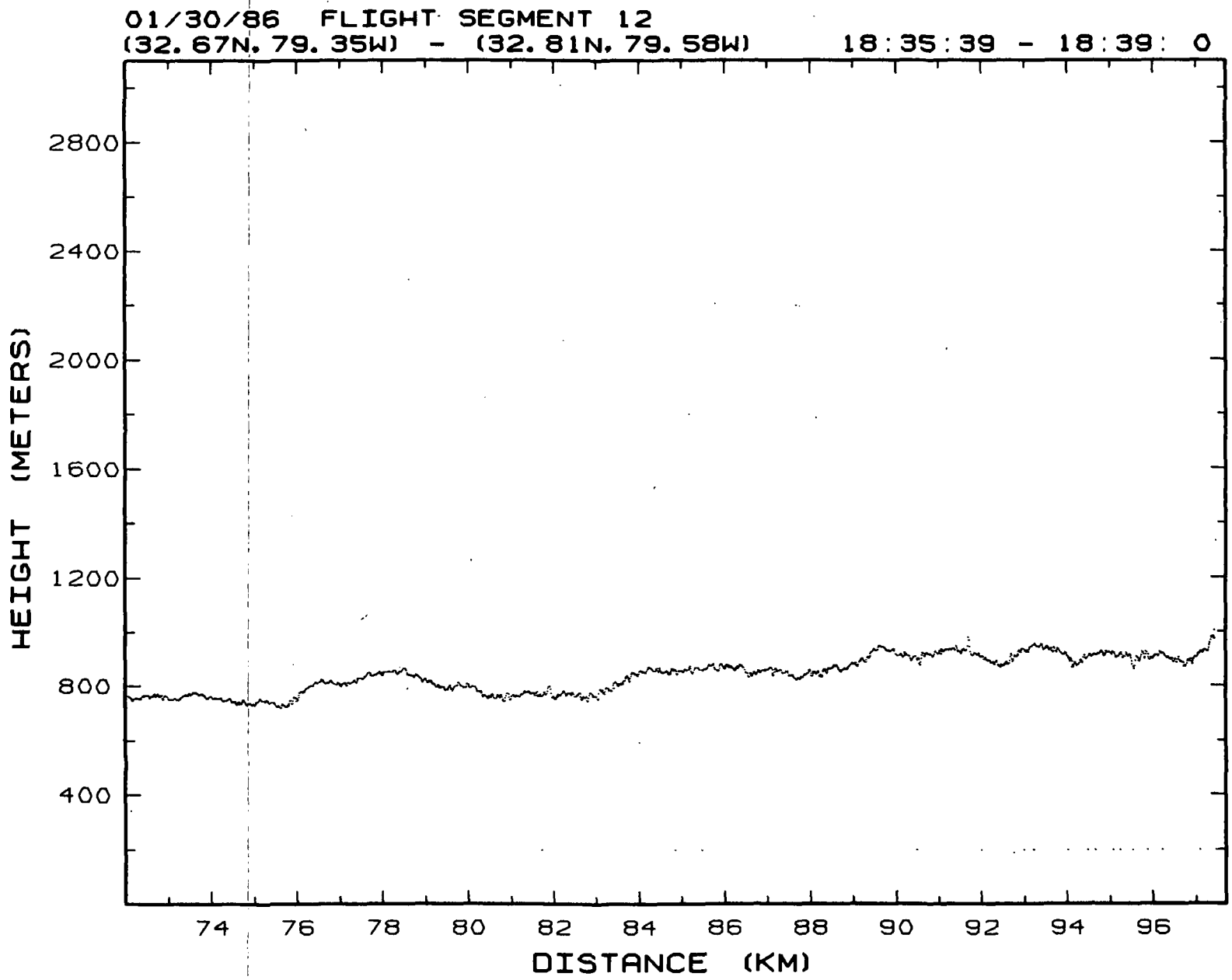

Figure 10.12d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 12, 72-98 km.

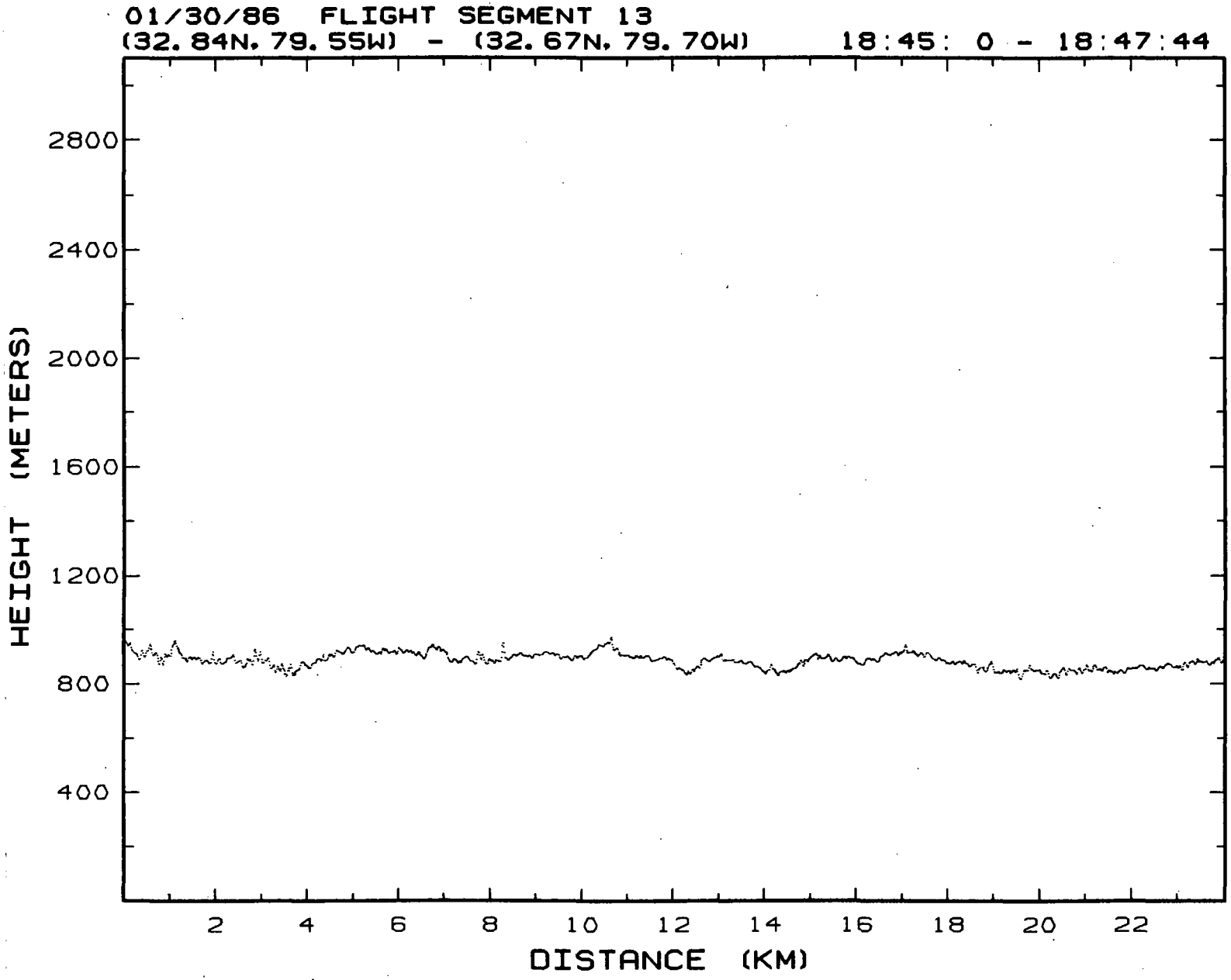

Figure 10.13a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 13, 0-24 km.

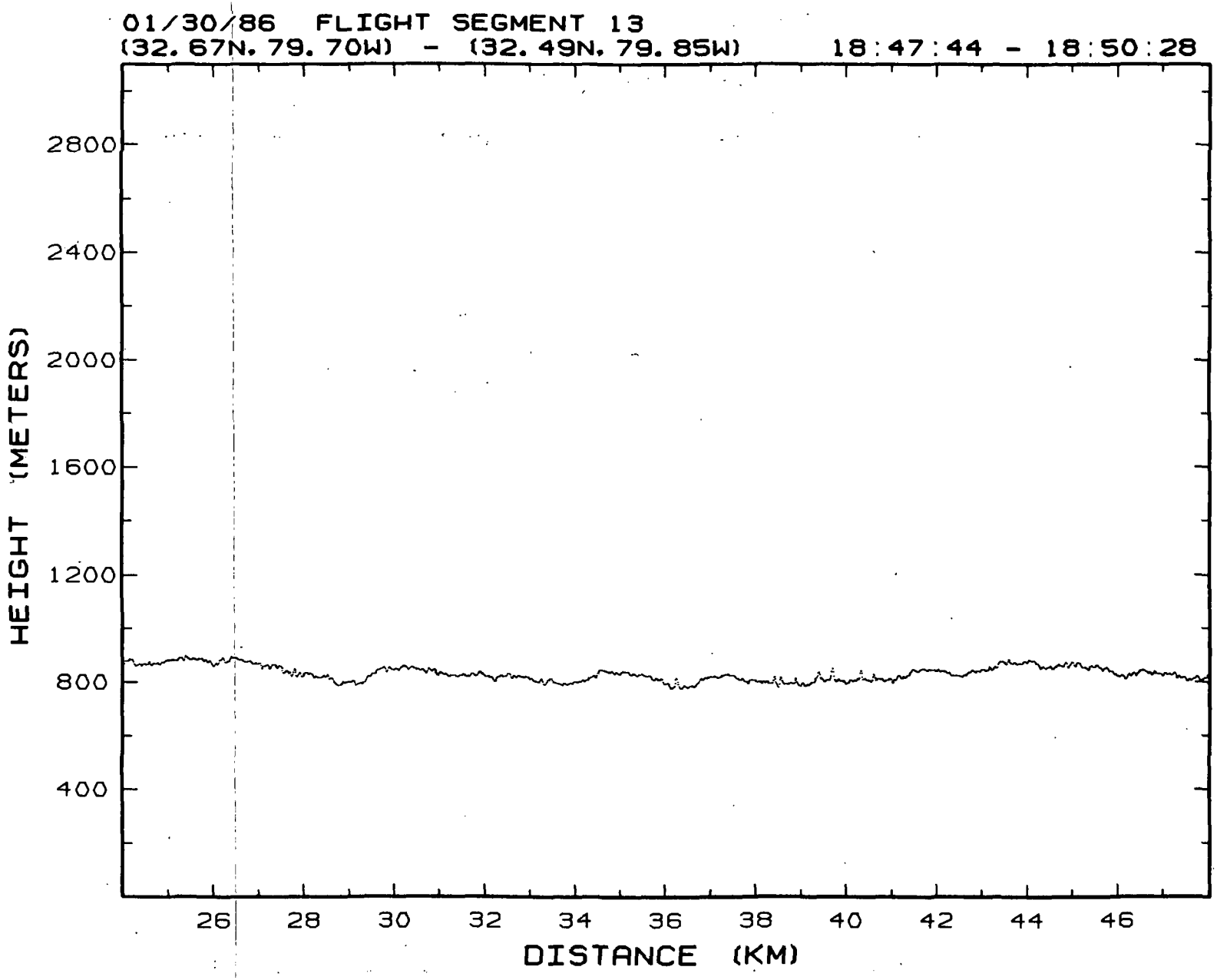

Figure 10.13b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 13, 24-48 km.

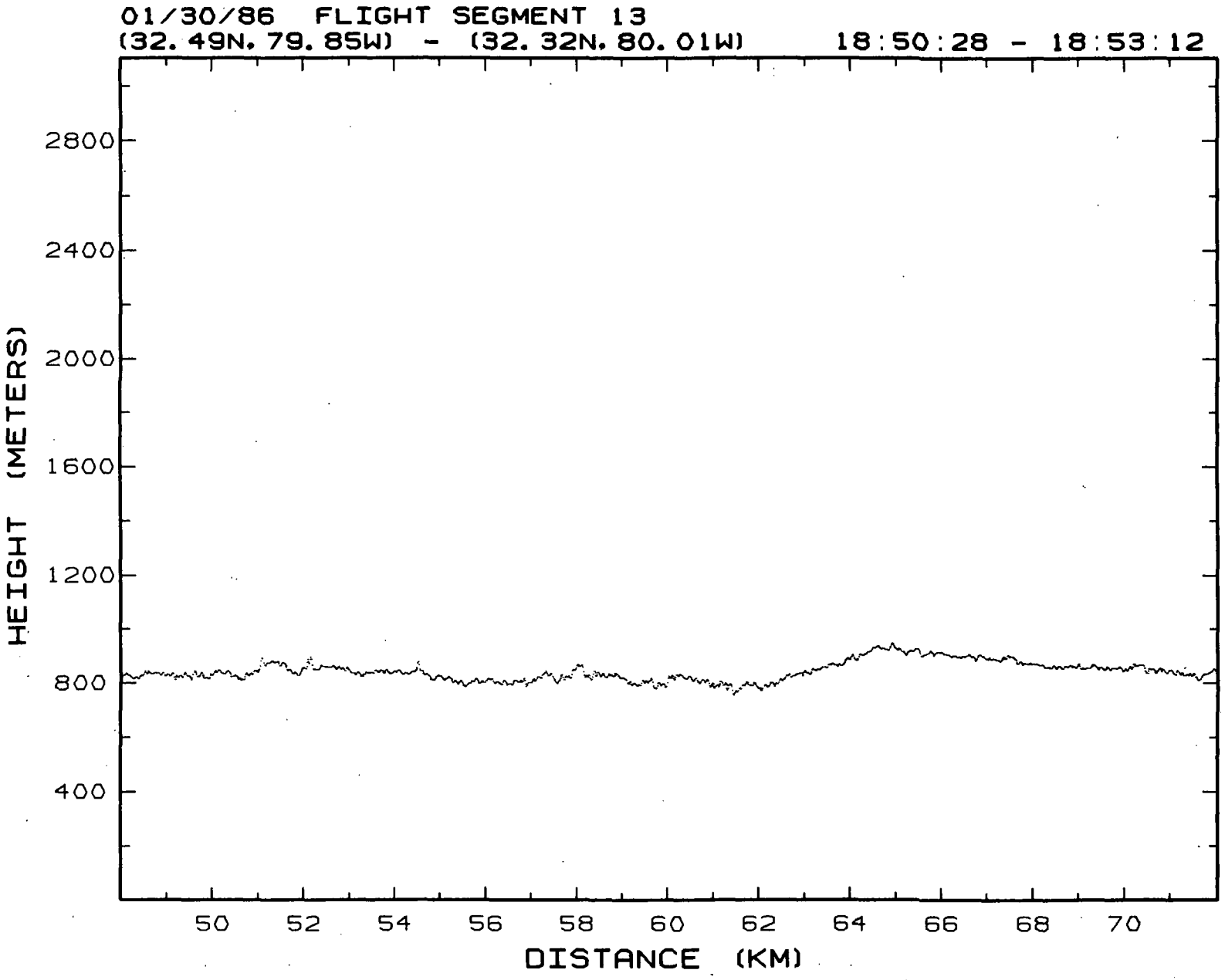

Figure 10.13c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 13, 48-72 km.

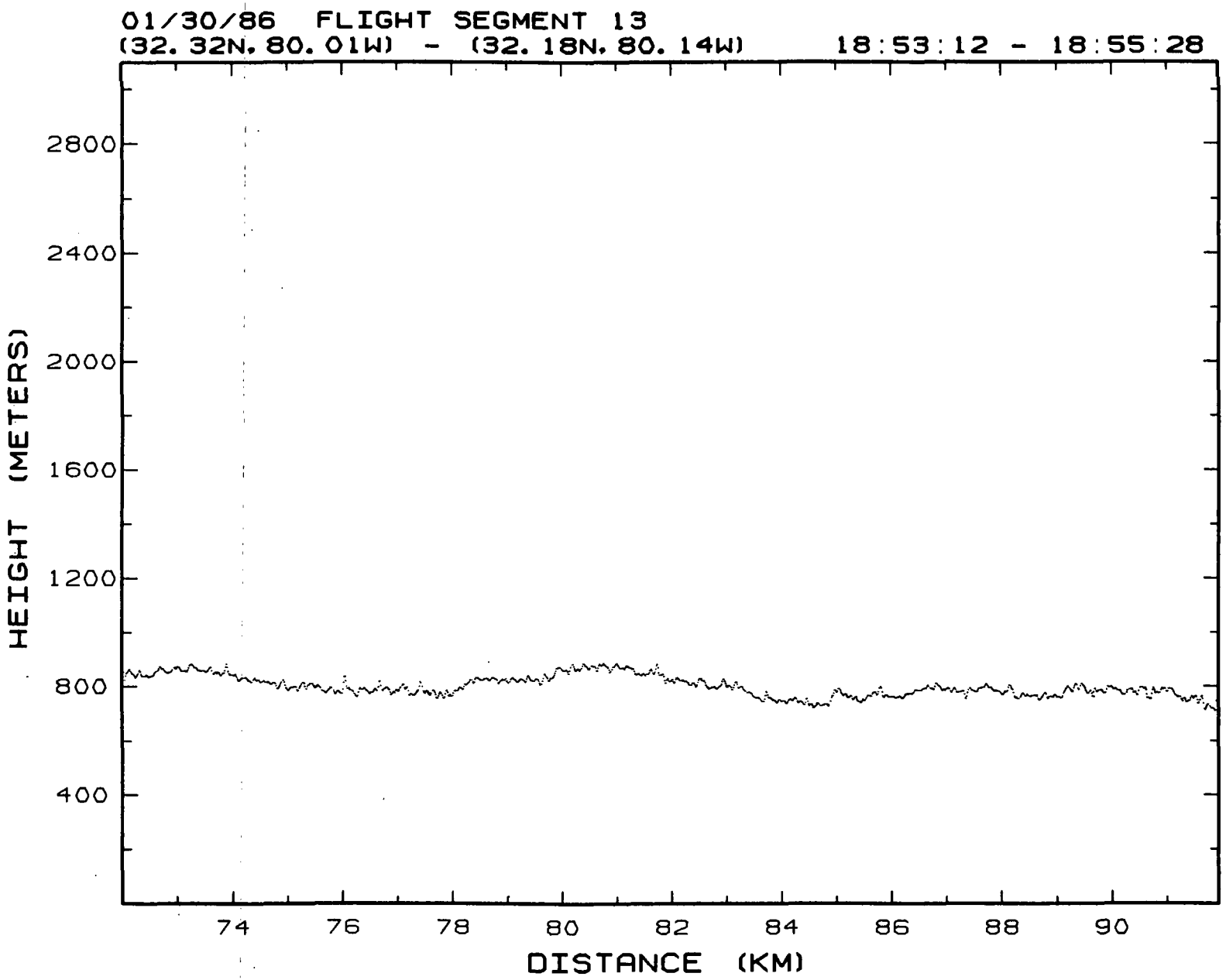

Figure 10.13d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 13, 72-92 km.

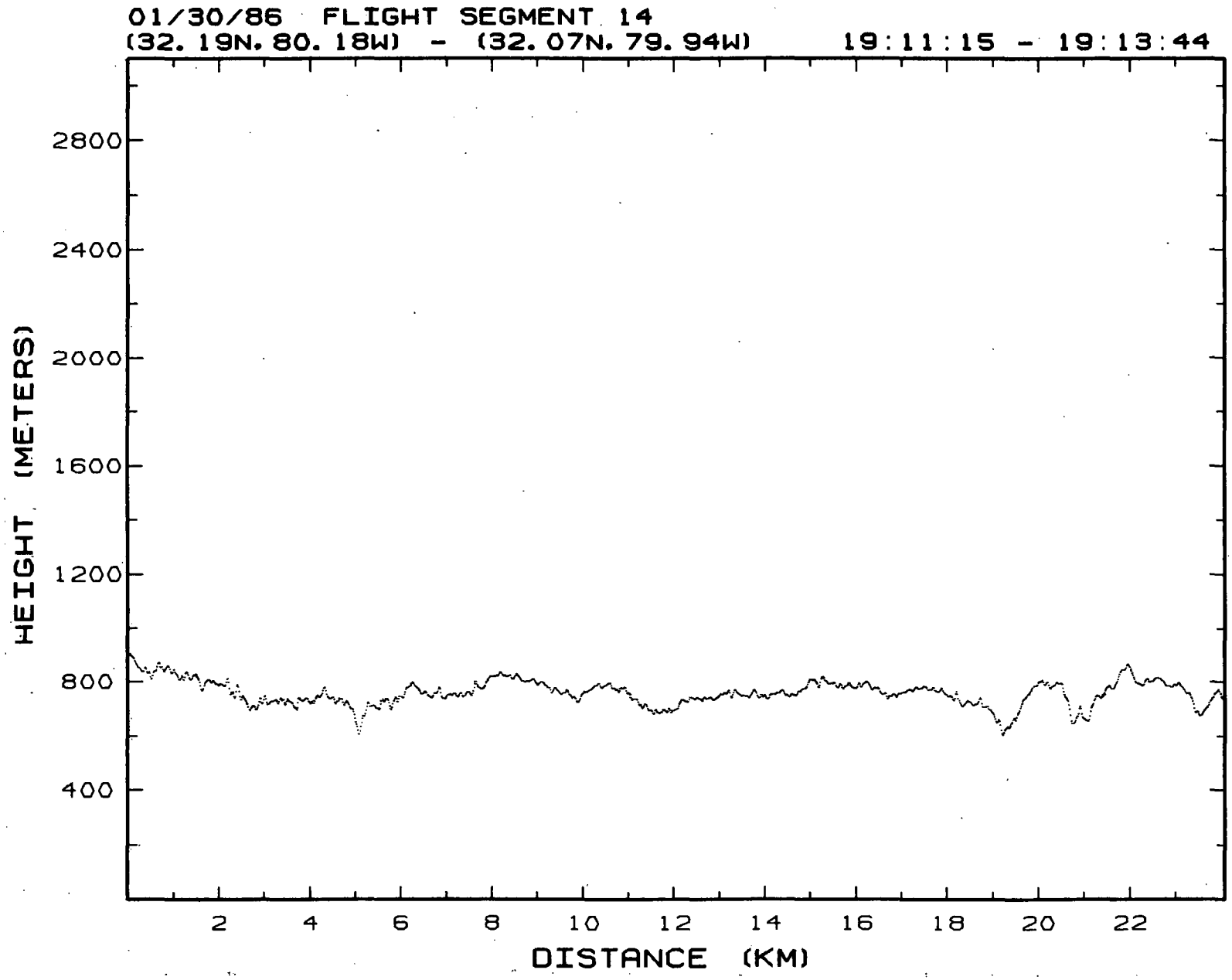

Figure 10.14a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 14, 0-24 km.

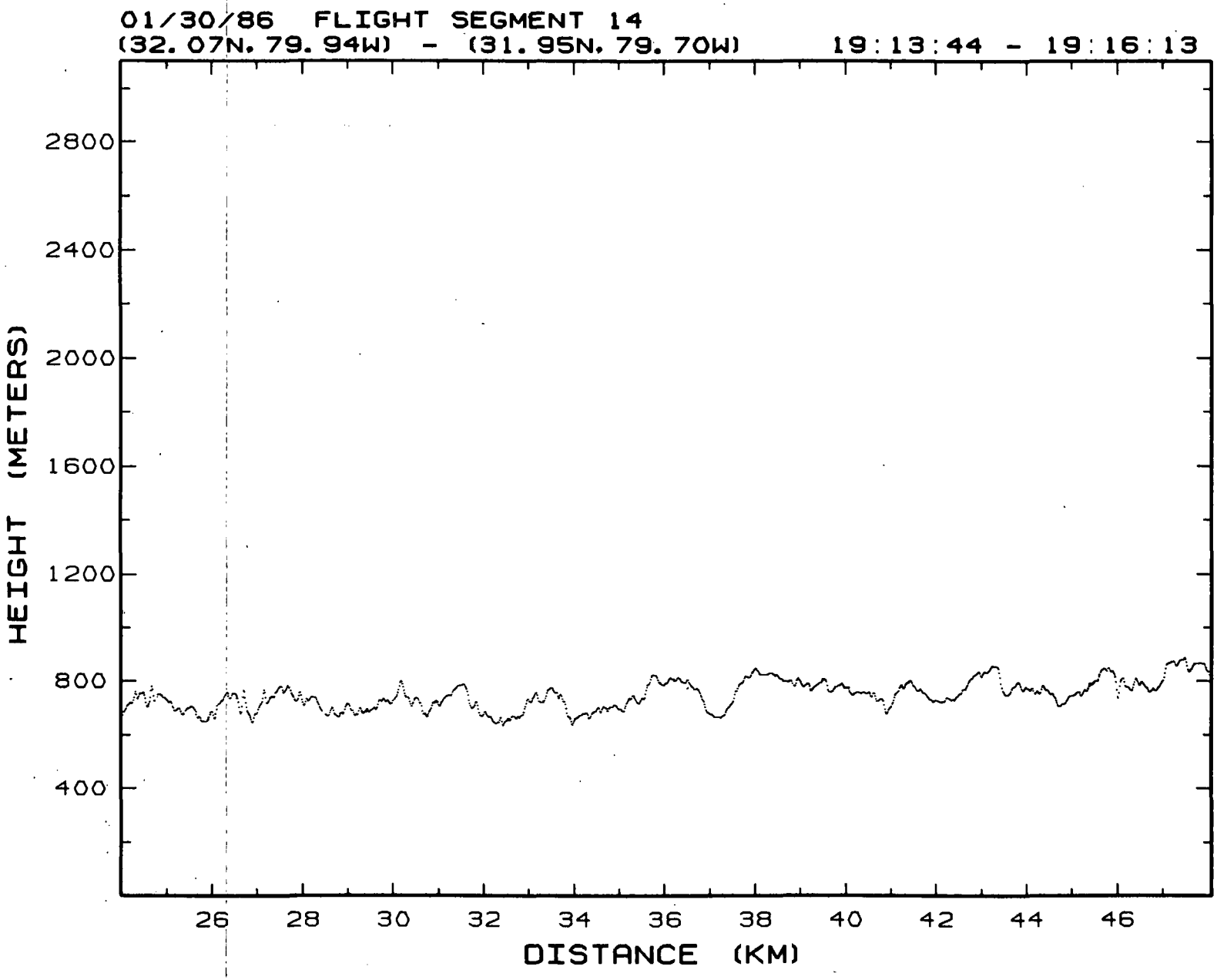

Figure 10.14b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 14, 24-48 km.

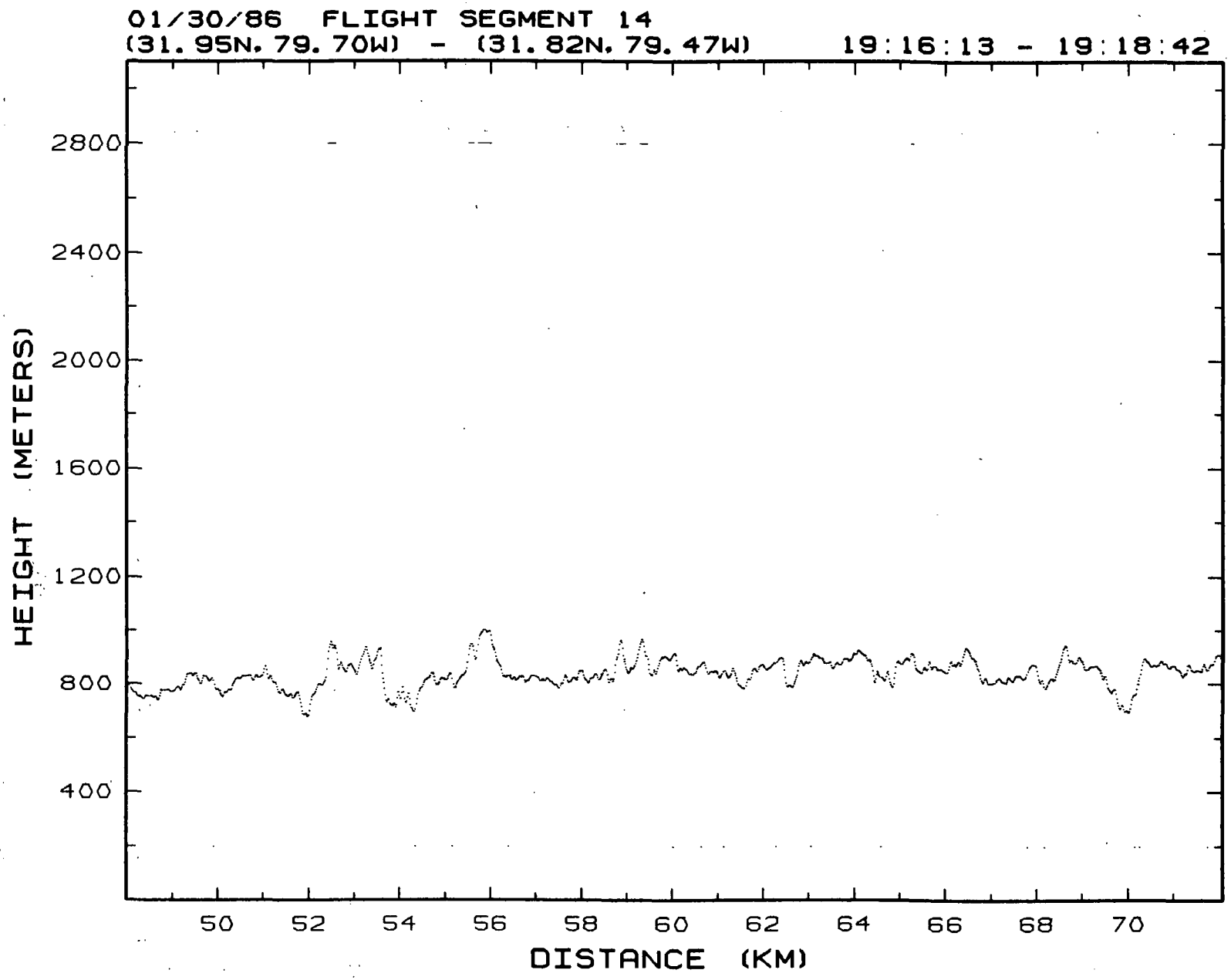

Figure 10.14c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 14, 48-72 km.

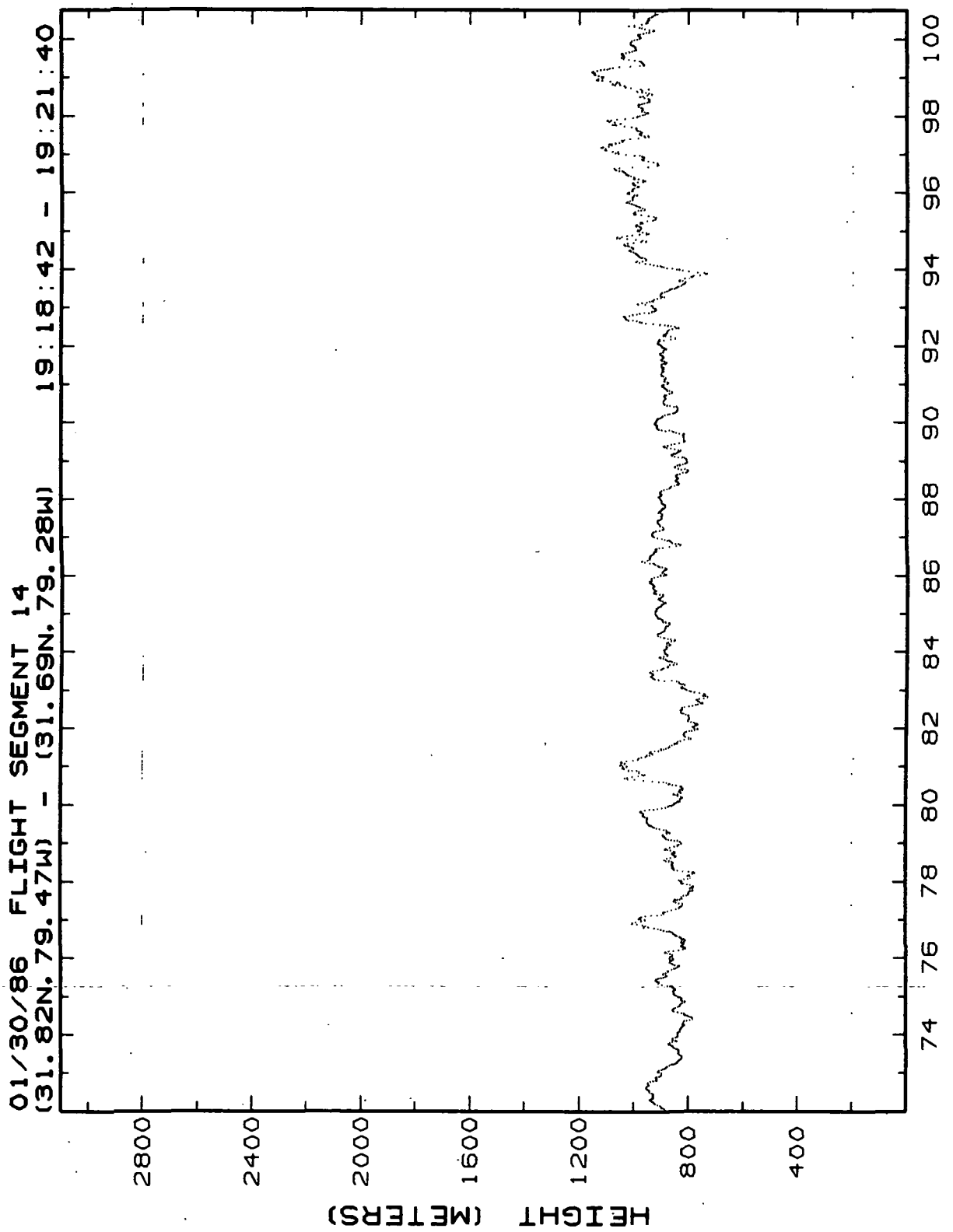

Figure 10.14d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 14, 72-101 km.

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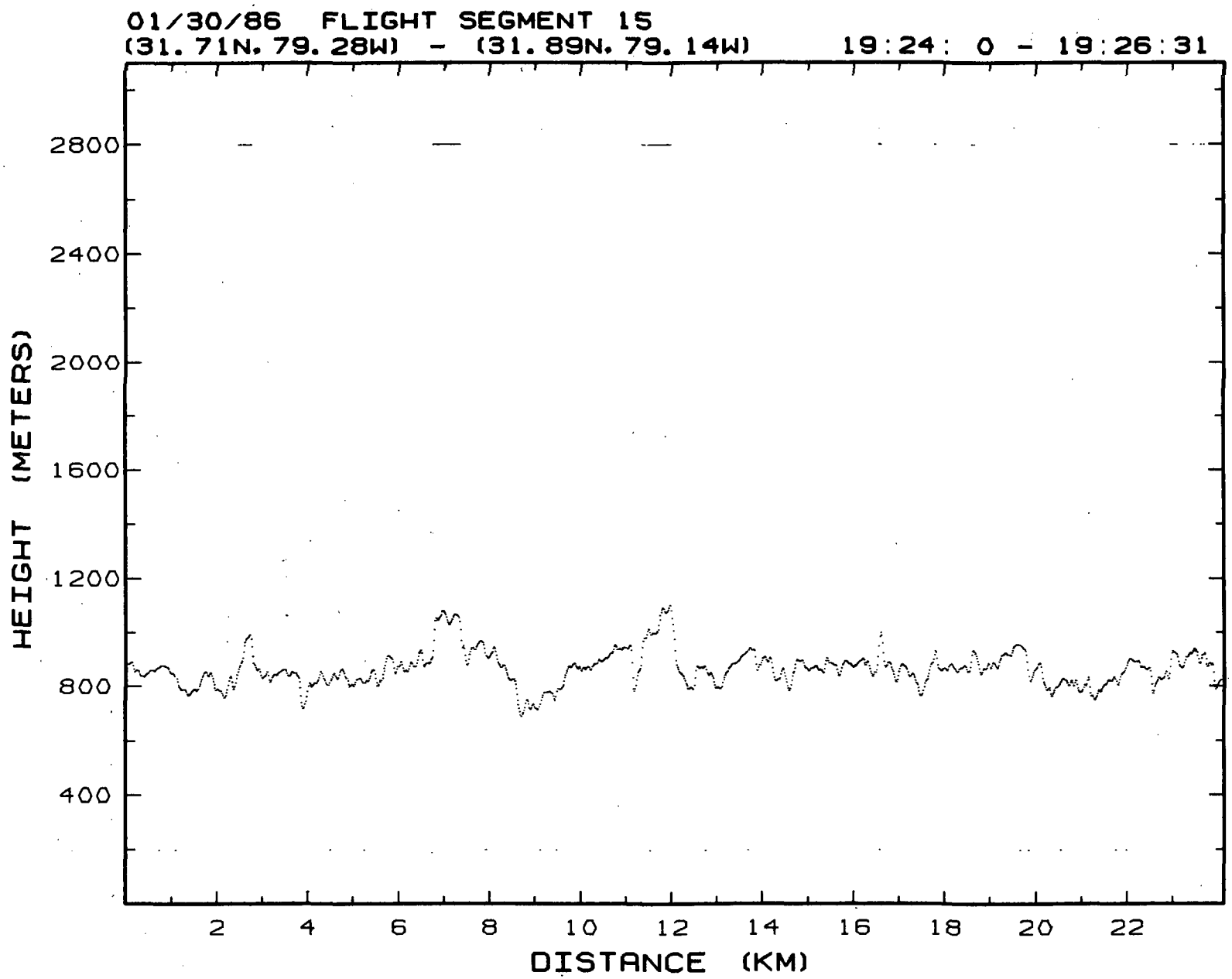

Figure 10.15a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 15, 0-24 km.

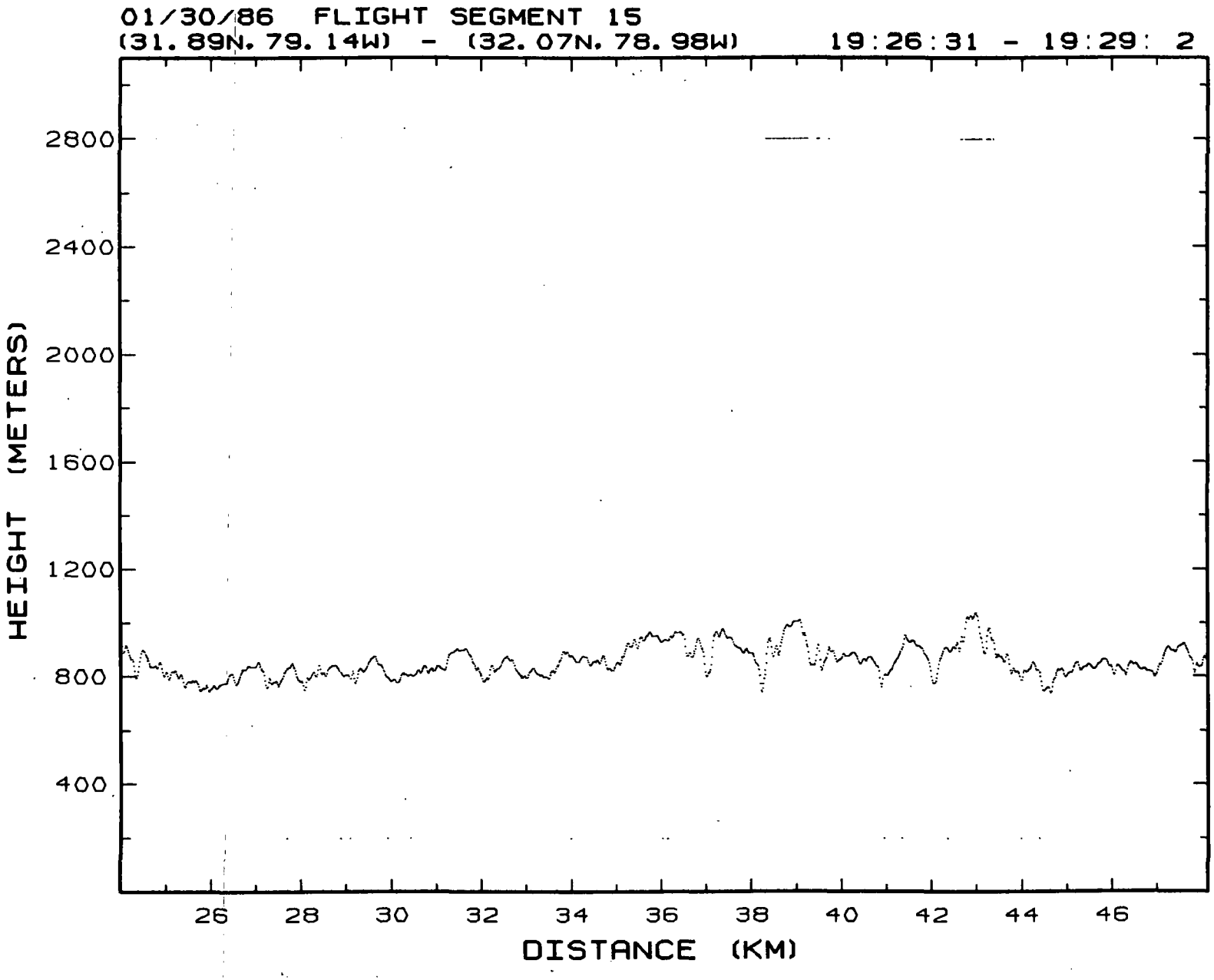

Figure 10.15b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 15, 24-48 km.

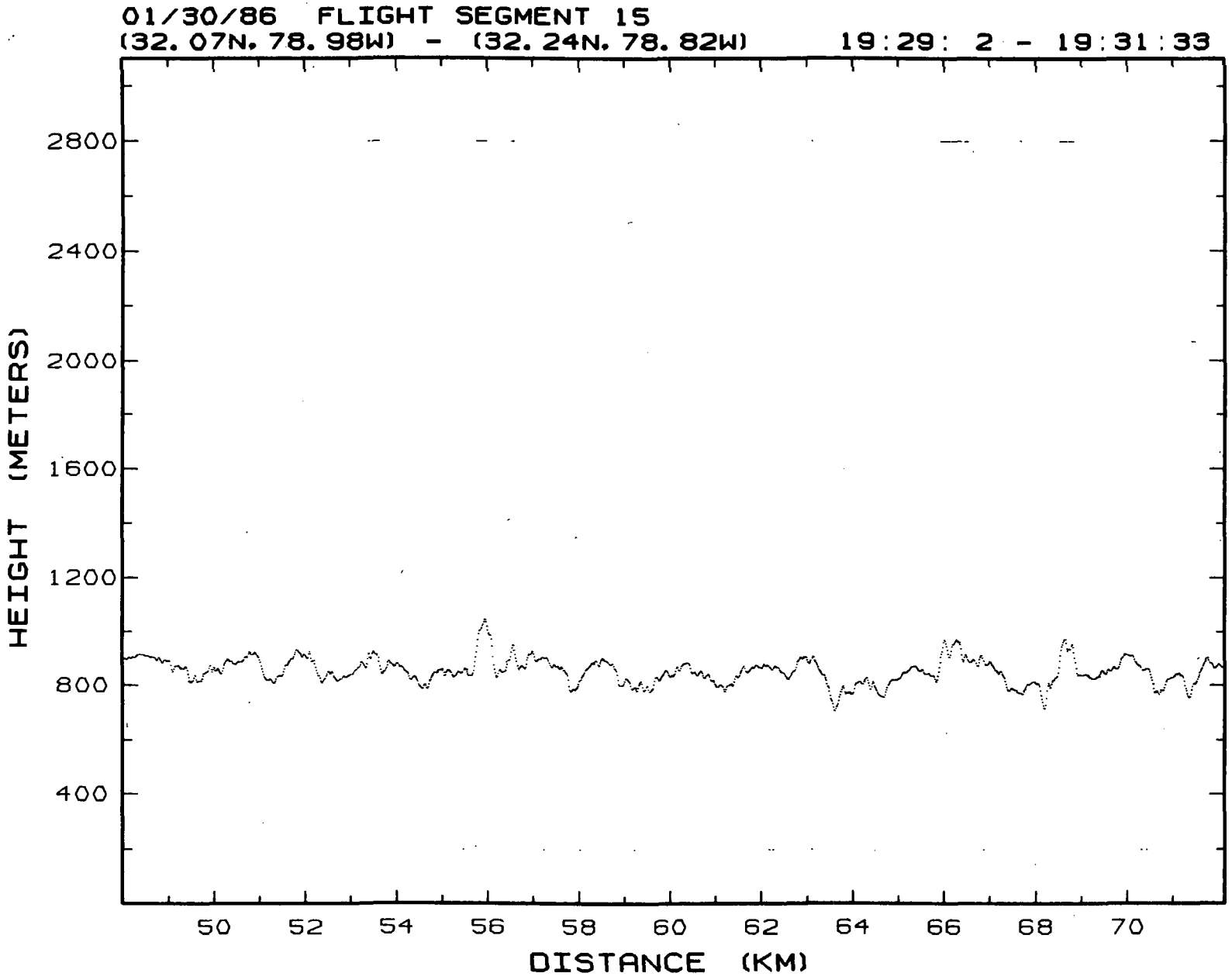

Figure 10.15c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 15, 48-72 km.

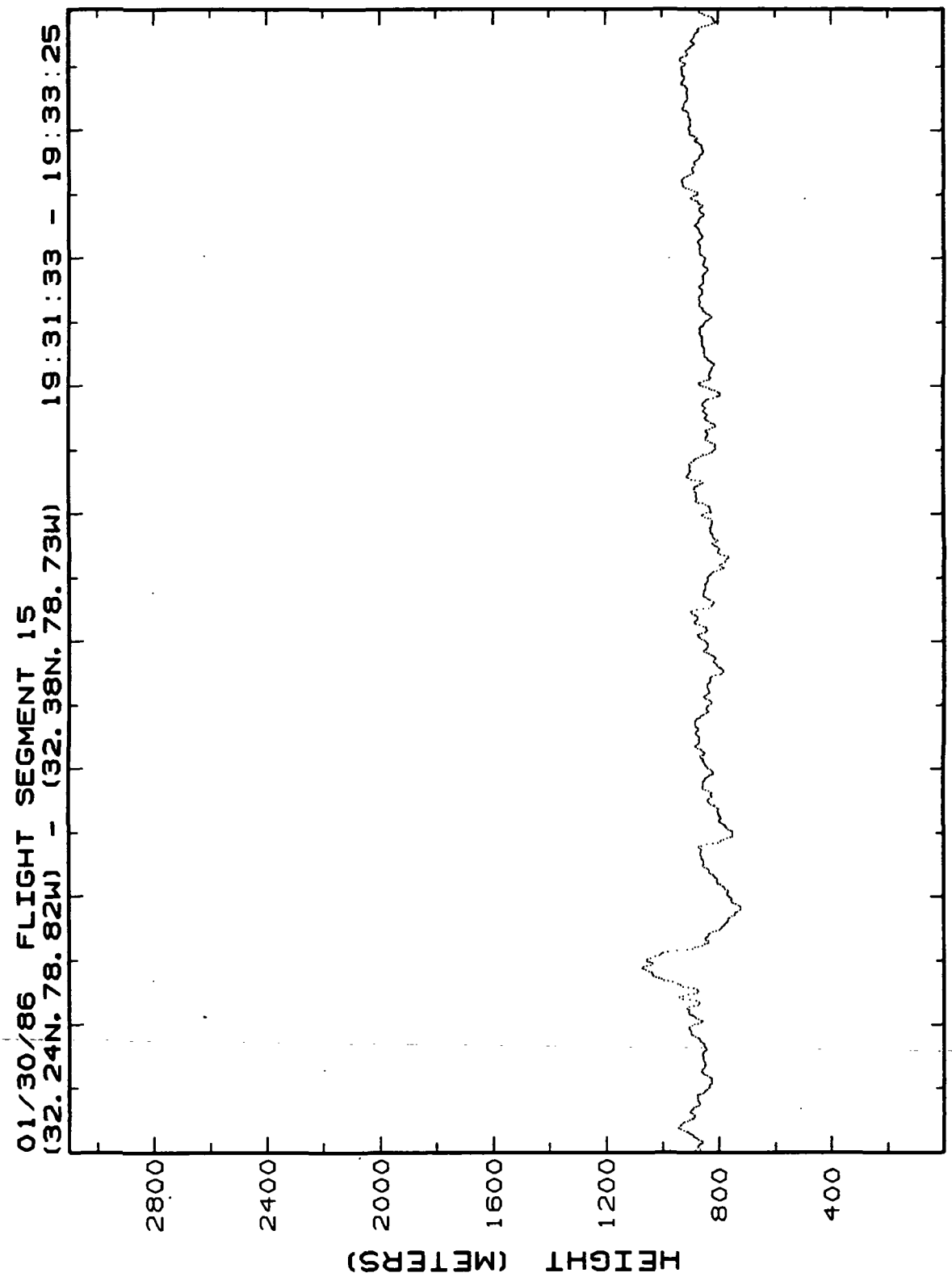

Figure 10.15d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 15, 72-90 km.

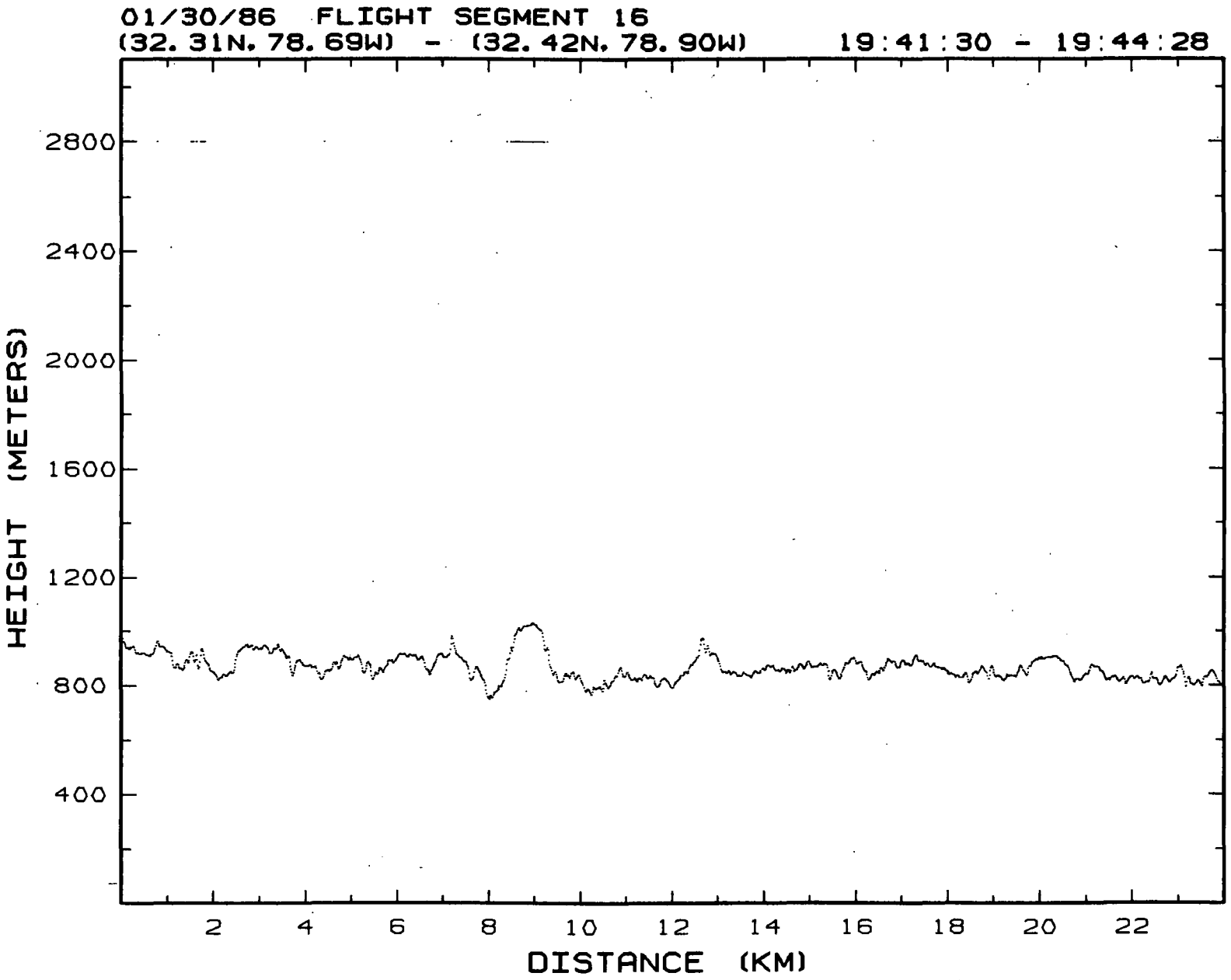

Figure 10.16a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 16, 0-24 km.

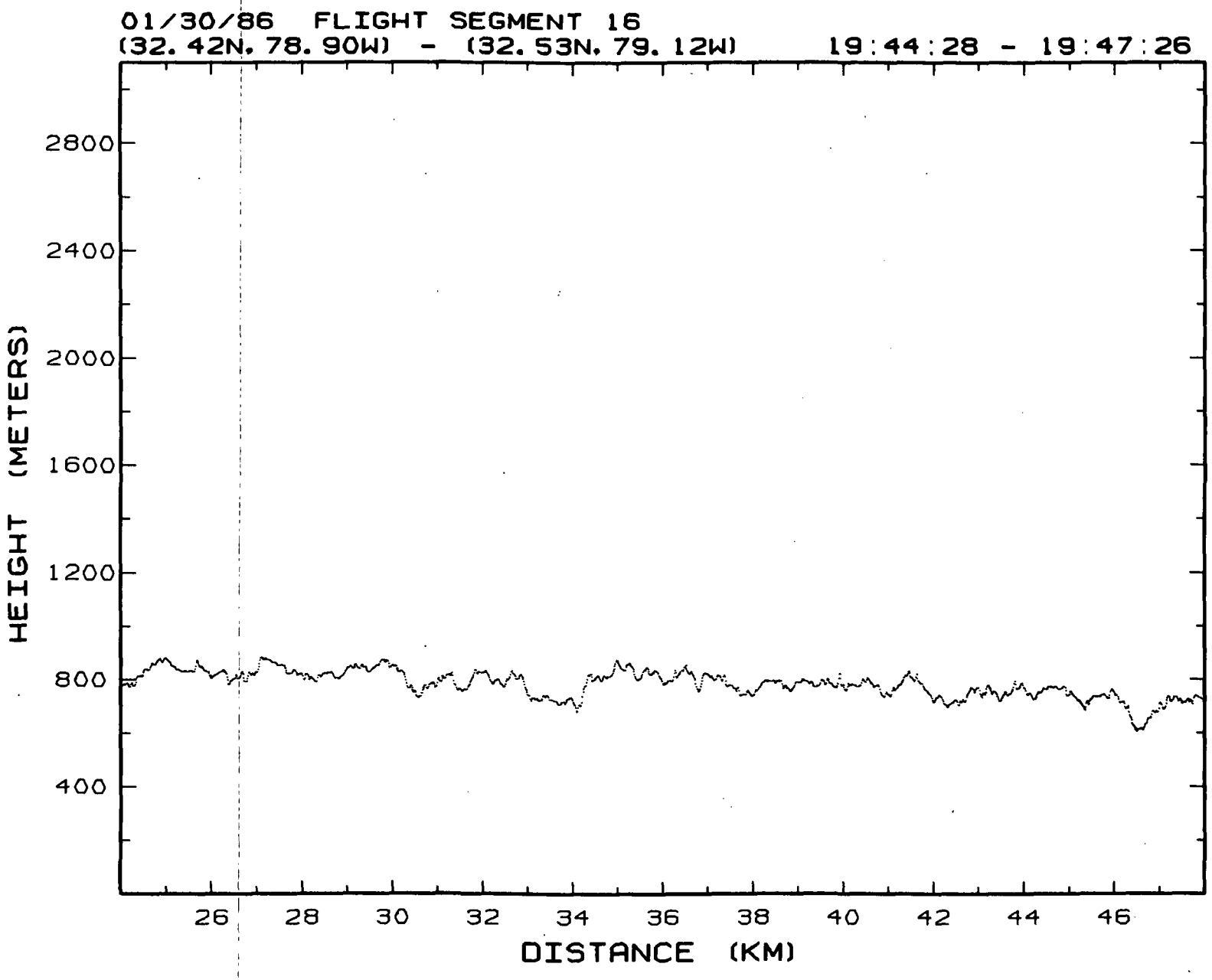

Figure 10.16b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 16, 24-48 km.

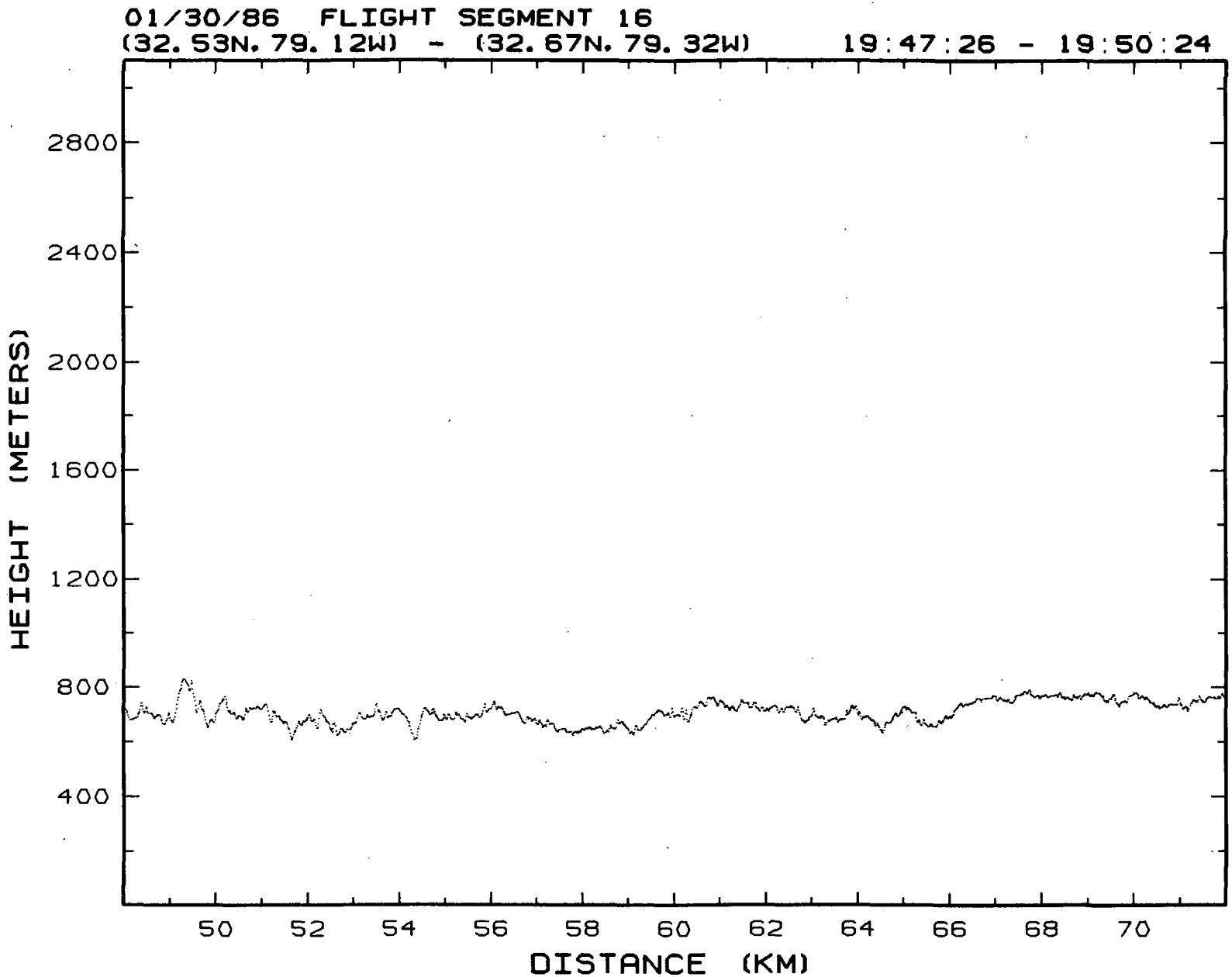

Figure 10.16c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 16, 48-72 km.

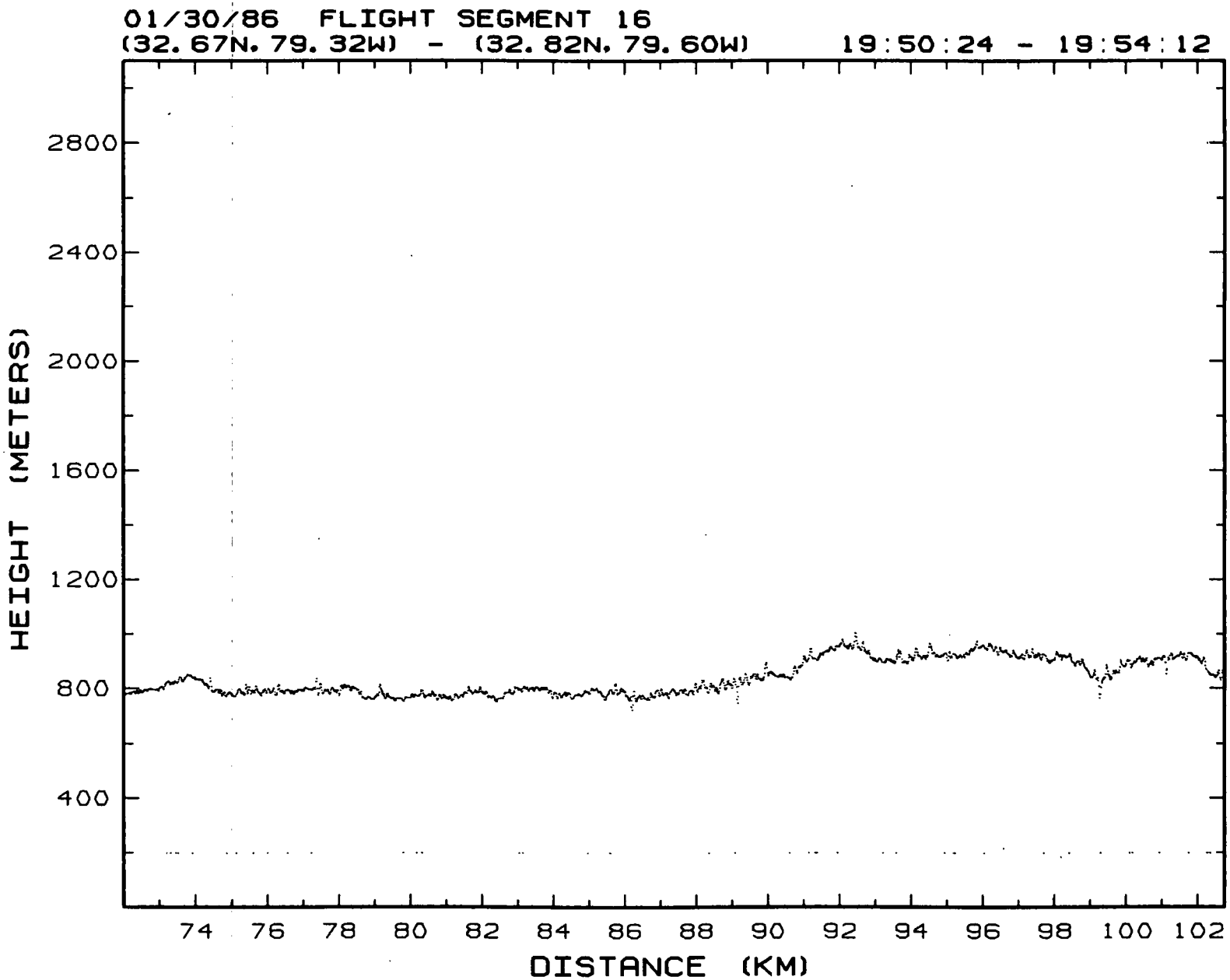

Figure 10.16d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 16, 72-103 km.

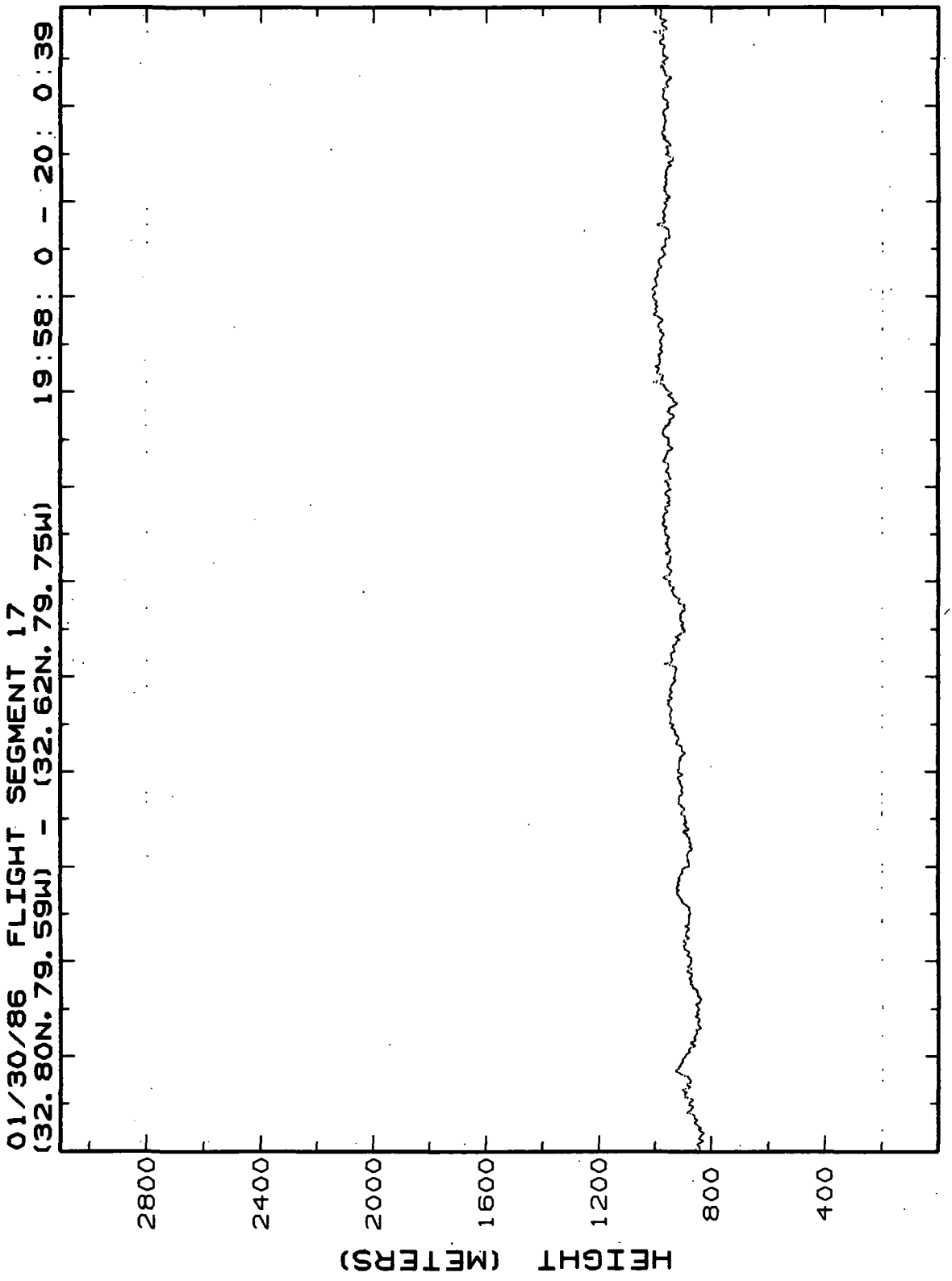

Figure 10.17a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 17, 0-24 km.

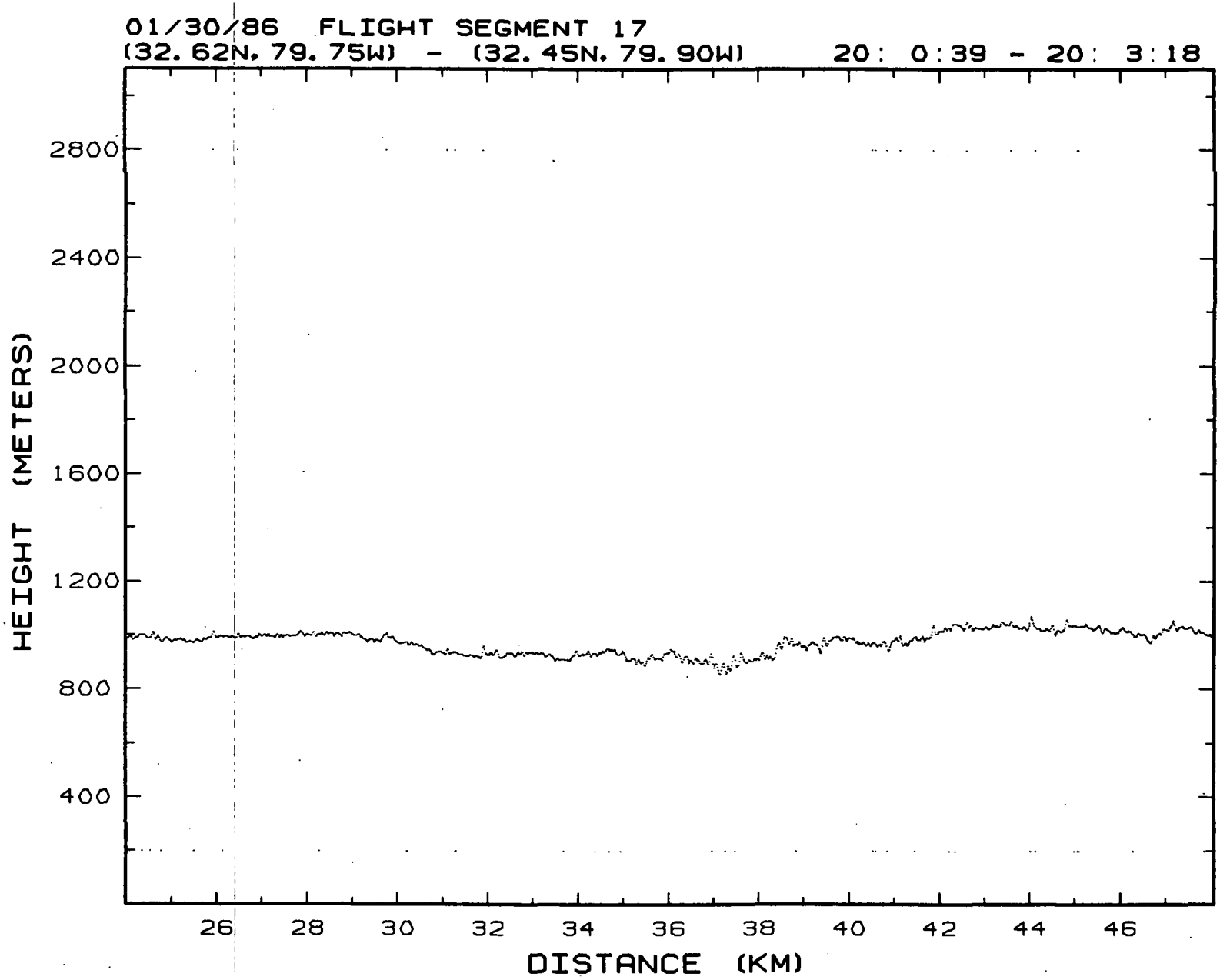

Figure 10.17b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 17, 24-48 km.

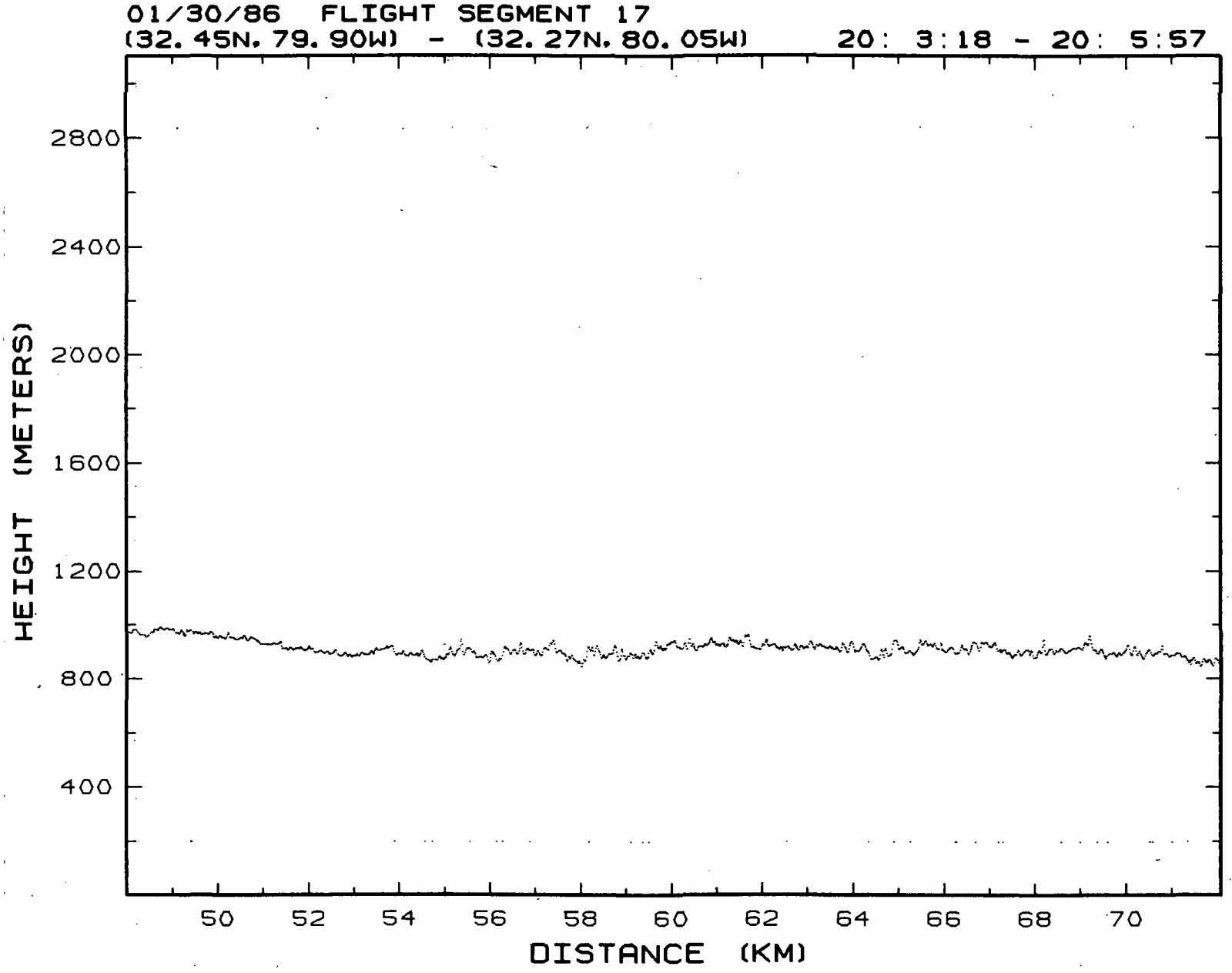

Figure 10.17c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 17, 48-72 km.

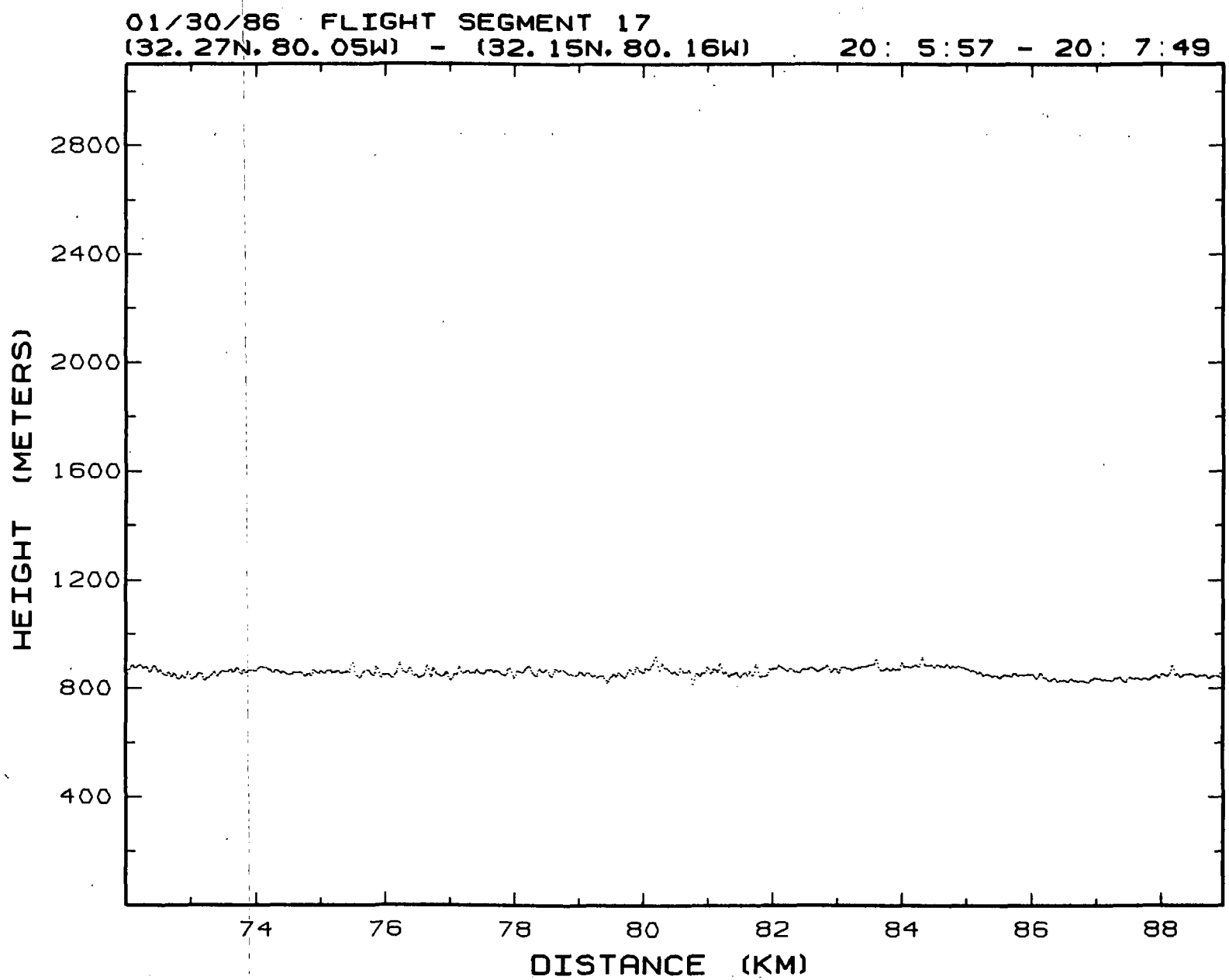

Figure 10.17d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 17, 72-89 km.

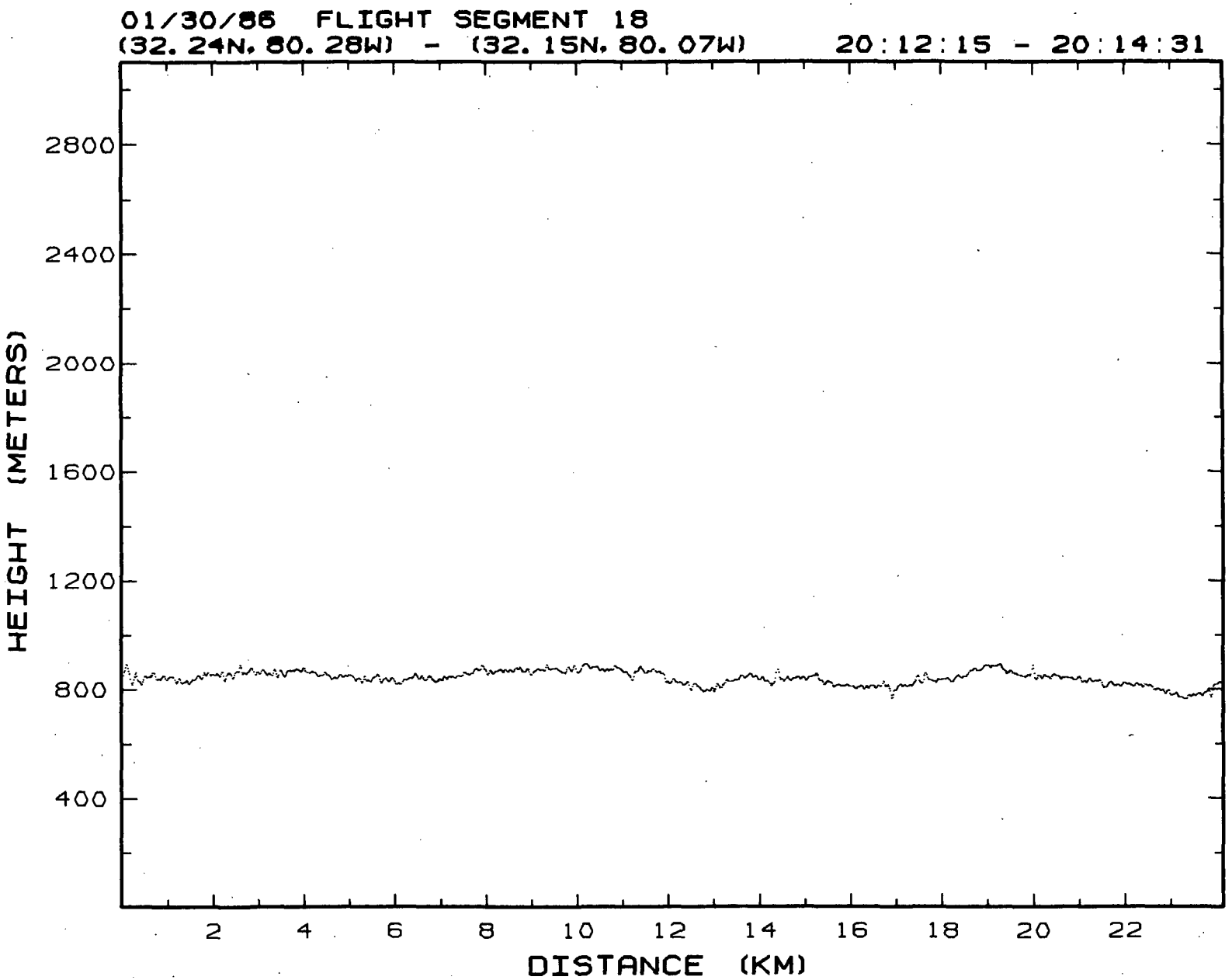

Figure 10.18a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 18, 0-24 km.

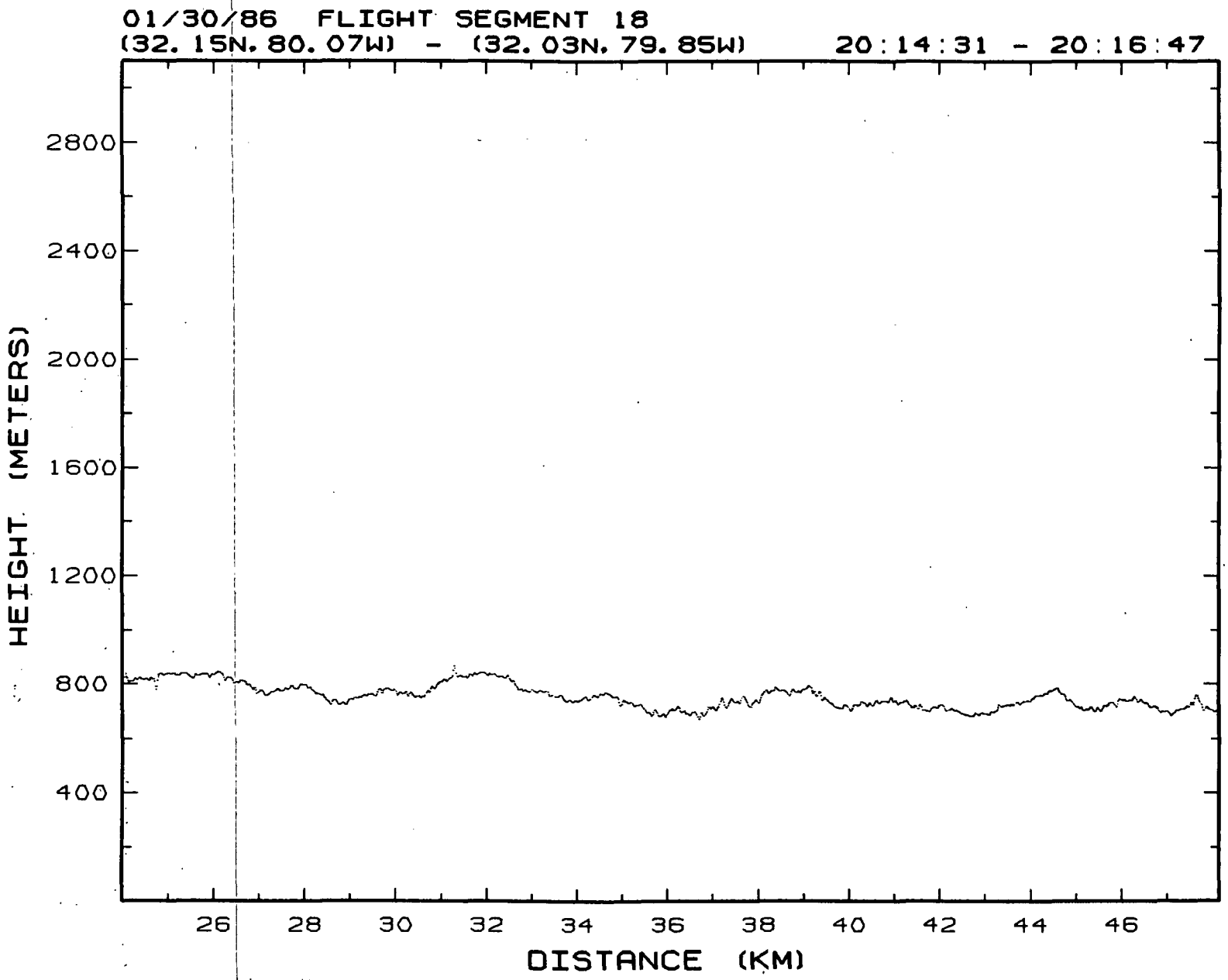

Figure 10.18b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 18, 24-48 km.

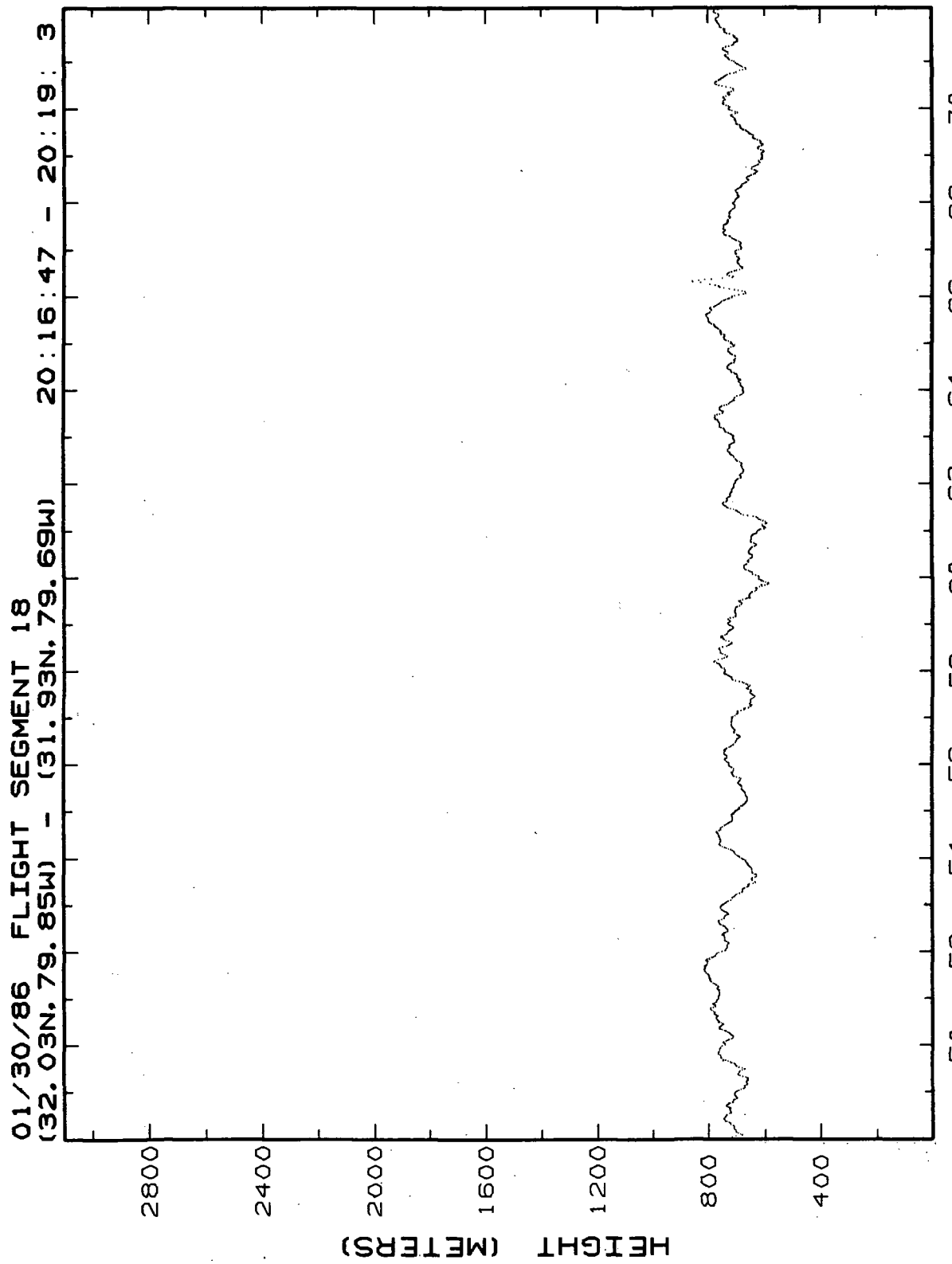

Figure 10.18c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 18, 48-72 km.

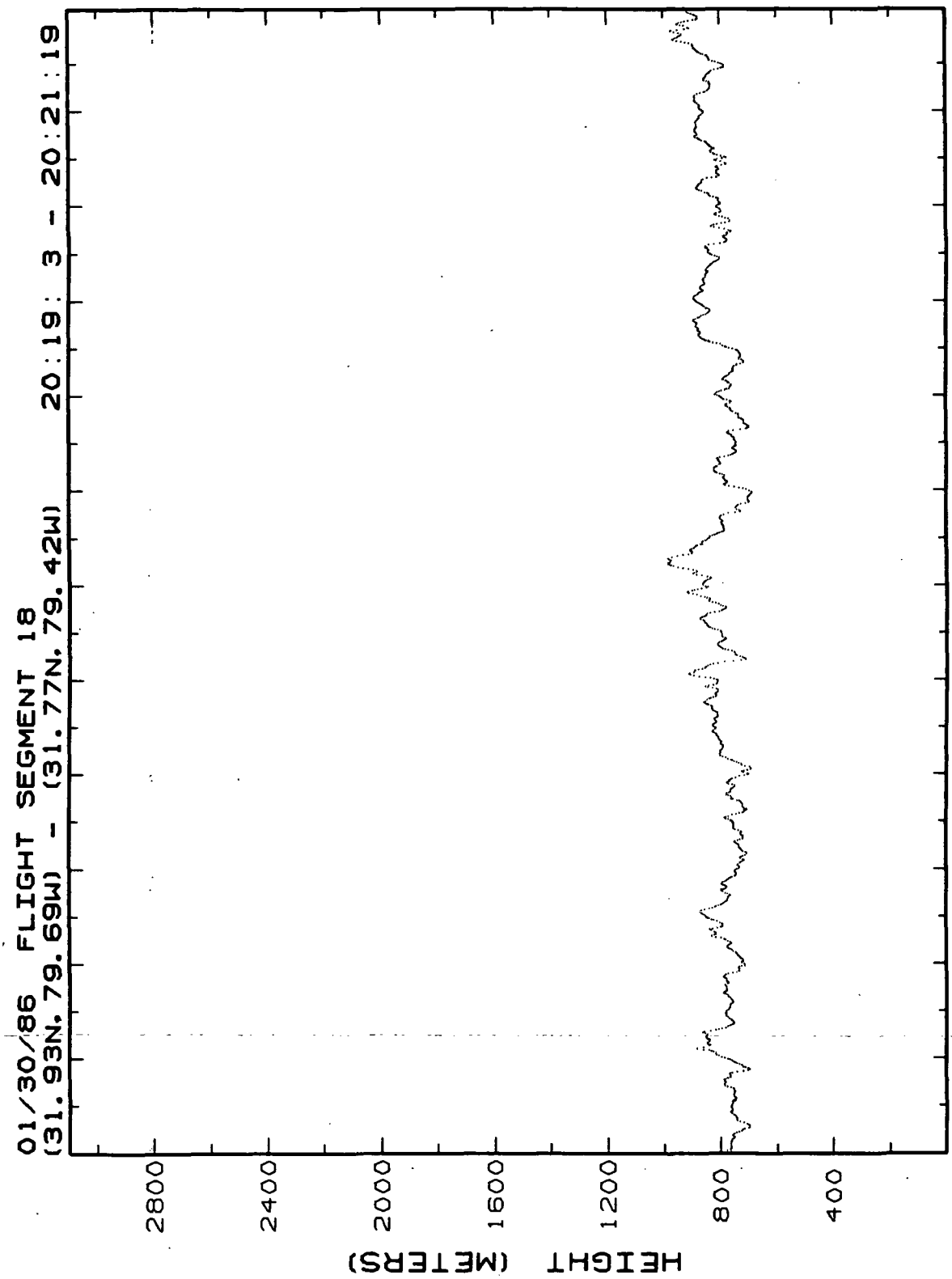

Figure 10.18d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 18, 72-96 km.

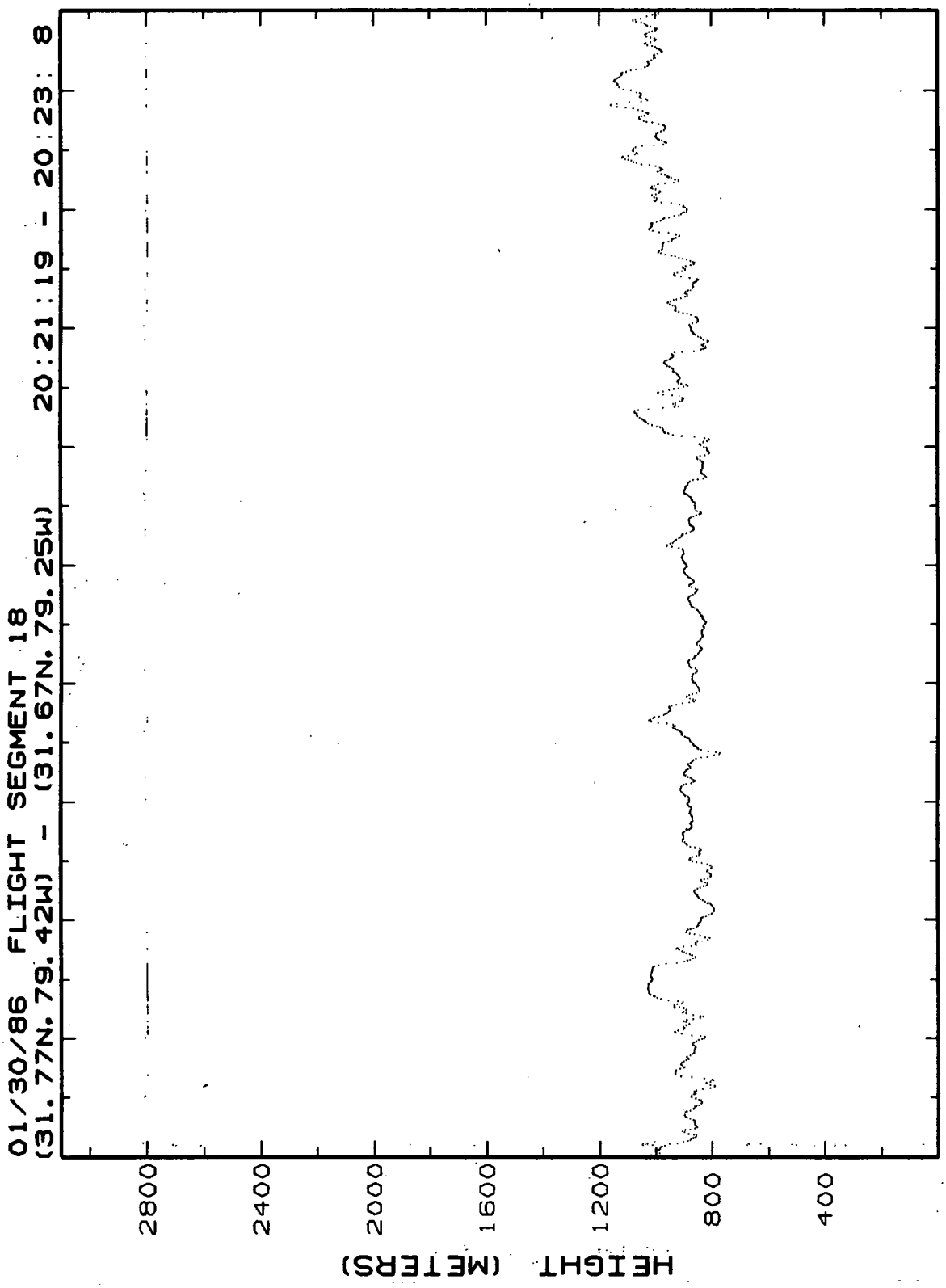

Figure 10.18e. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 18, 96-115 km.

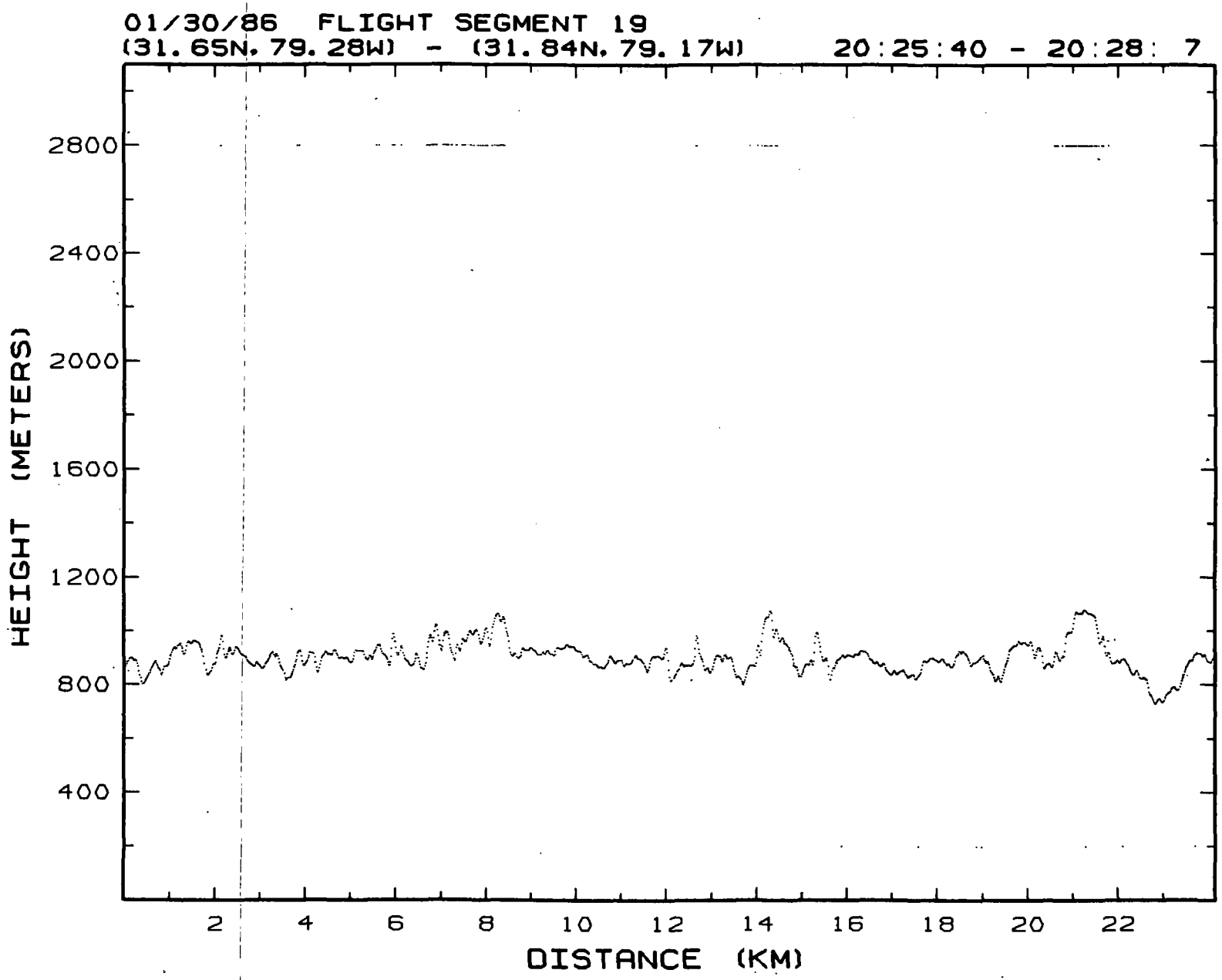

Figure 10.19a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 19, 0-24 km.

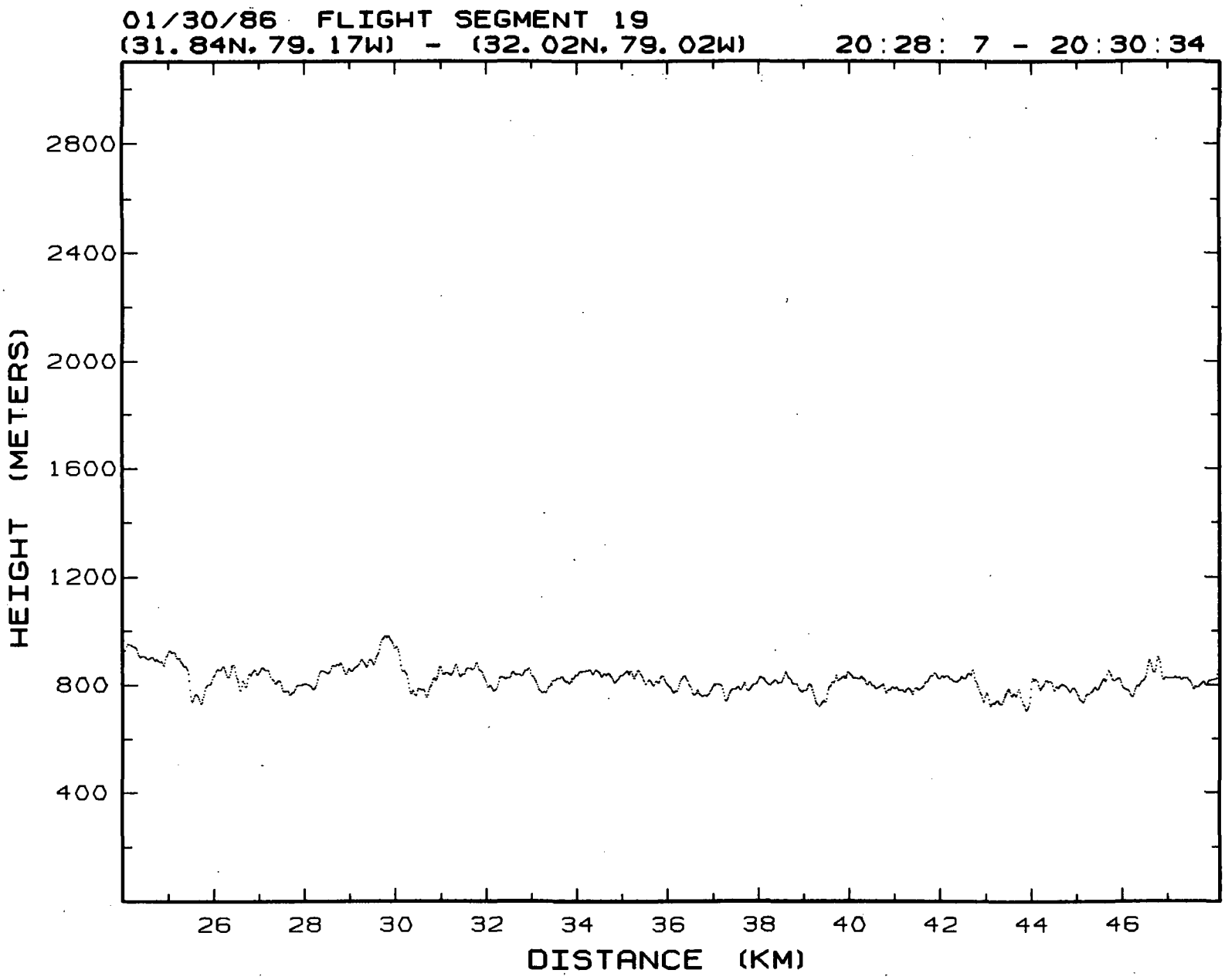

Figure 10.19b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 19, 24-48 km.

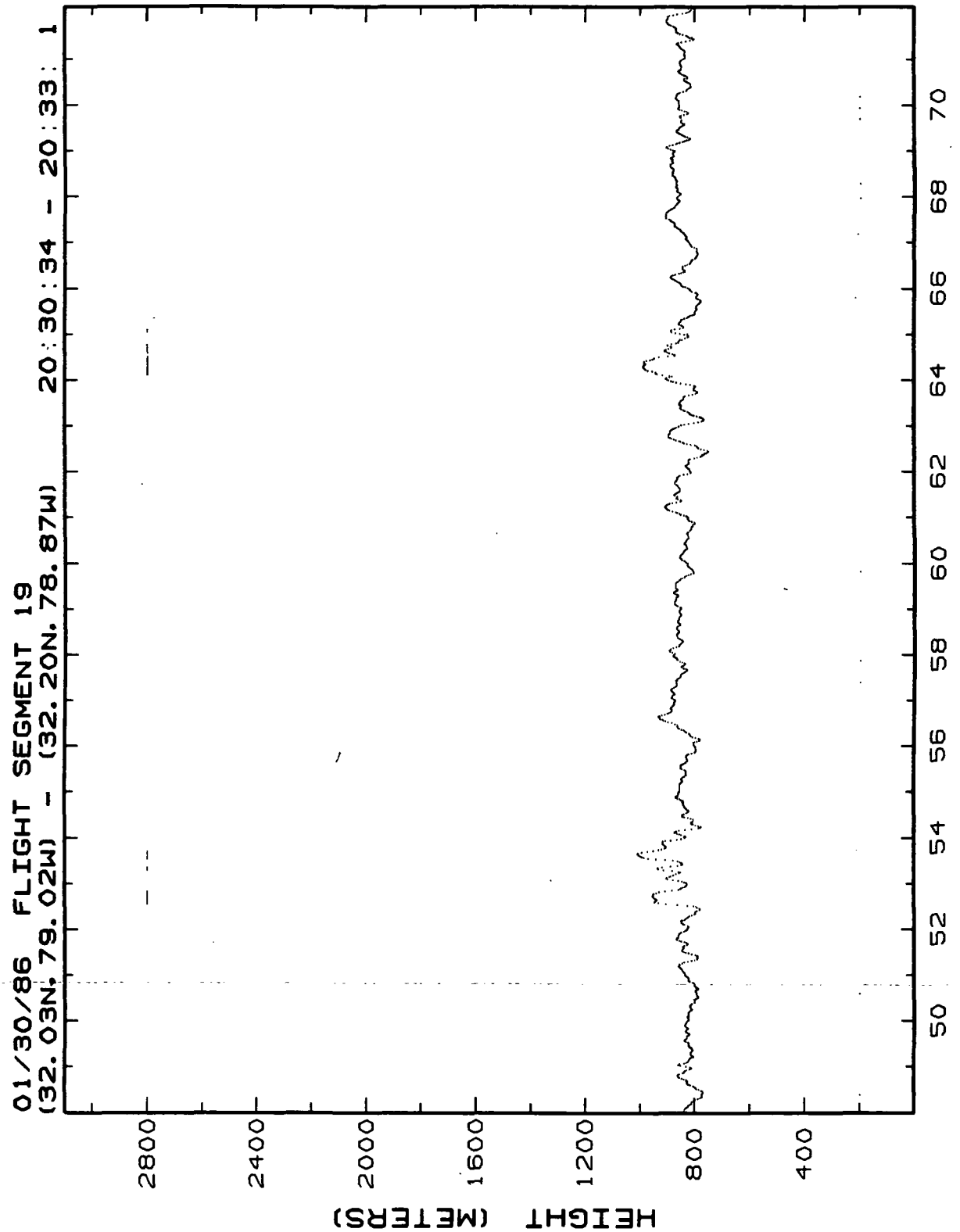

Figure 10.19c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 19, 48-72 km.

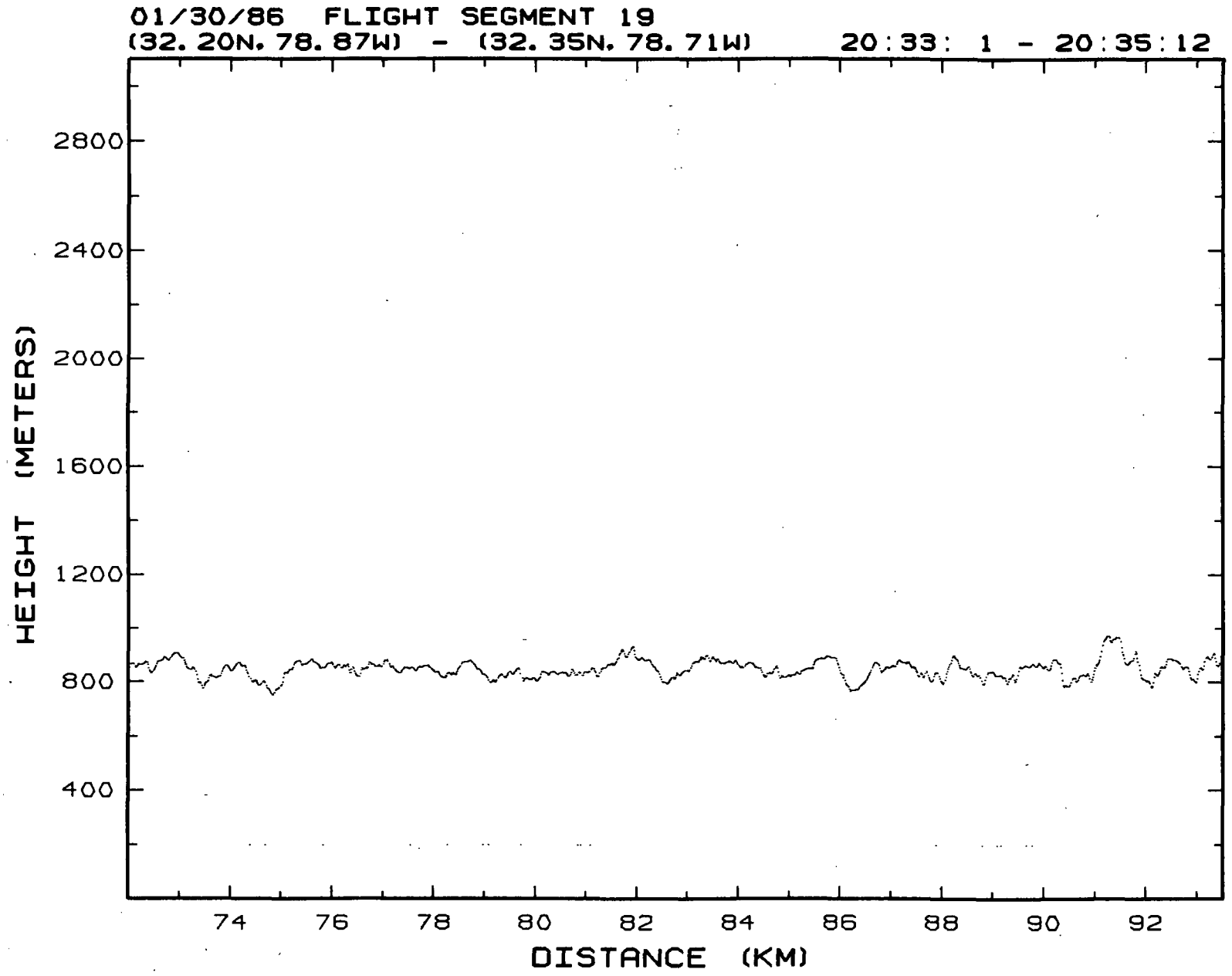

Figure 10.19d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 19, 72-93 km.

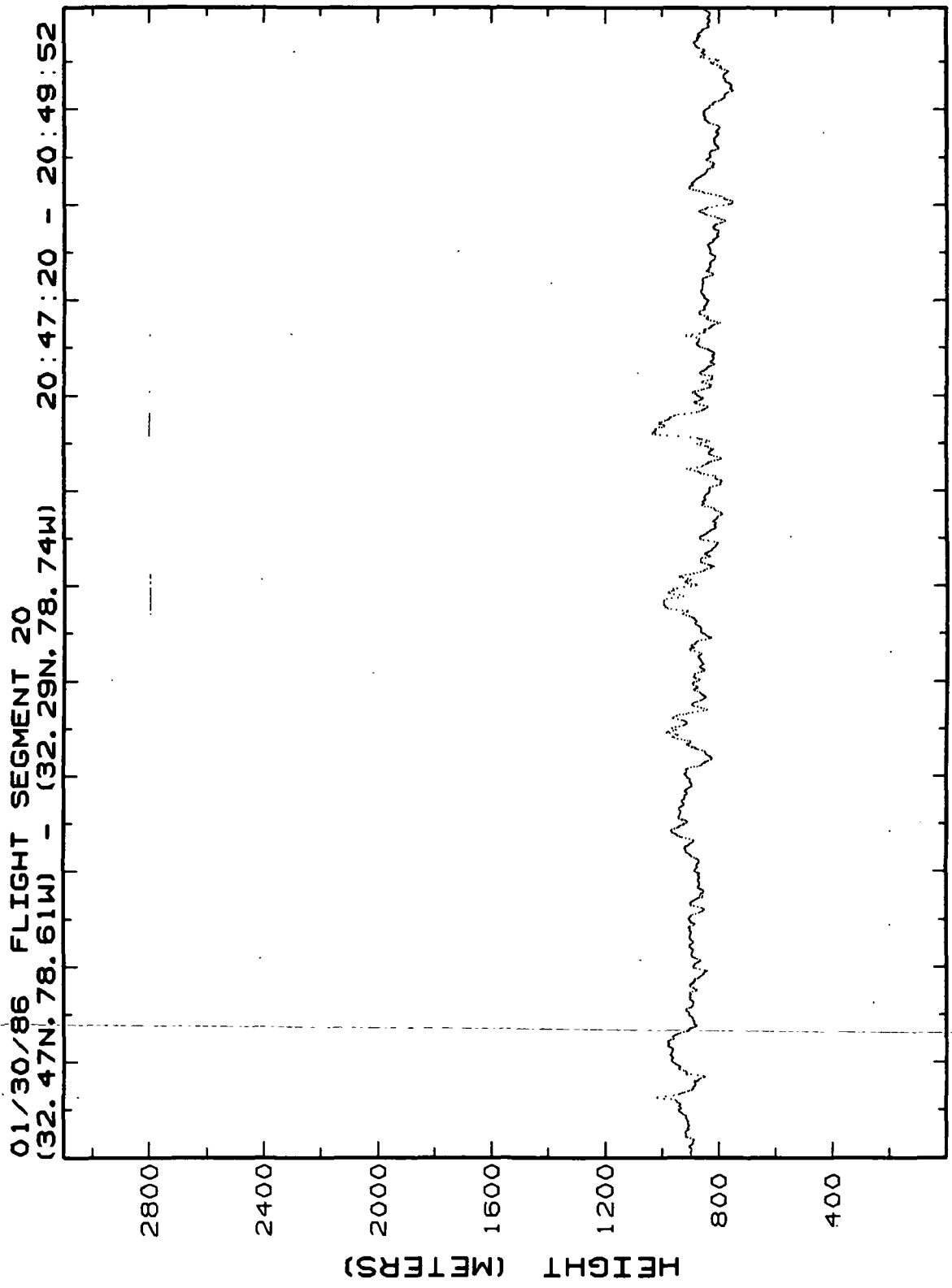

Figure 10.20a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 20, 0-24 km.

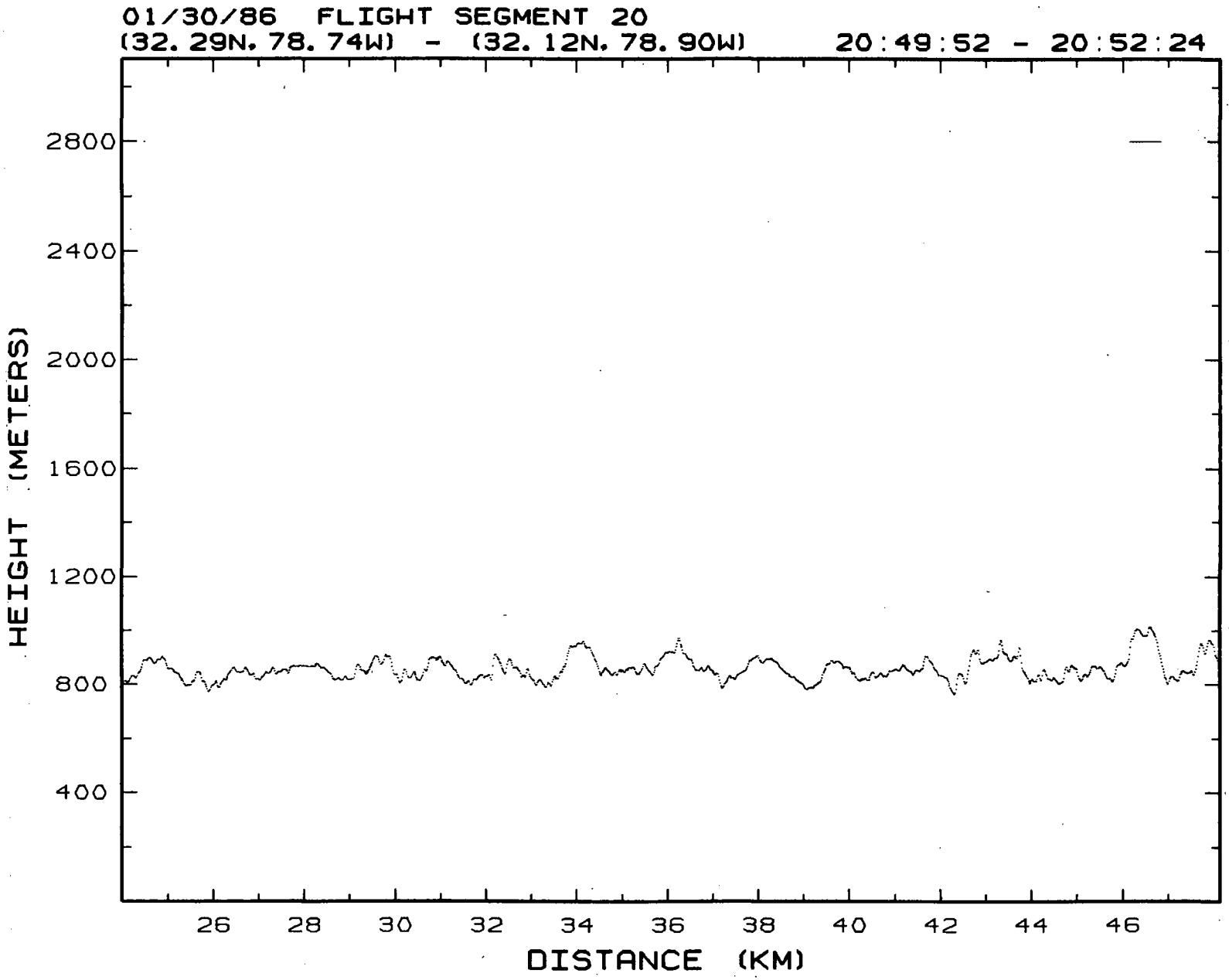

Figure 10.20b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 20, 24-48 km.

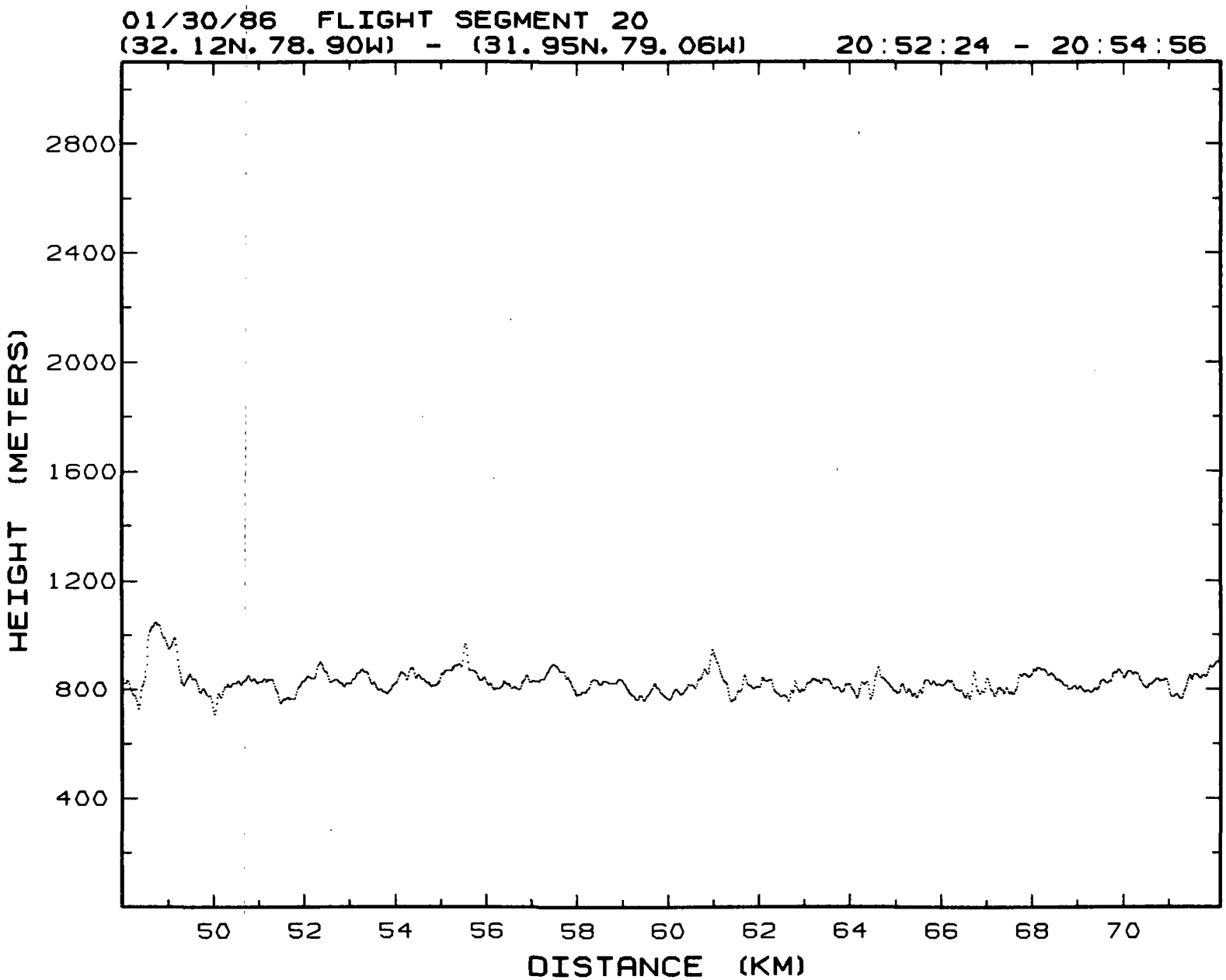

Figure 10.20c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 20, 48-72 km.

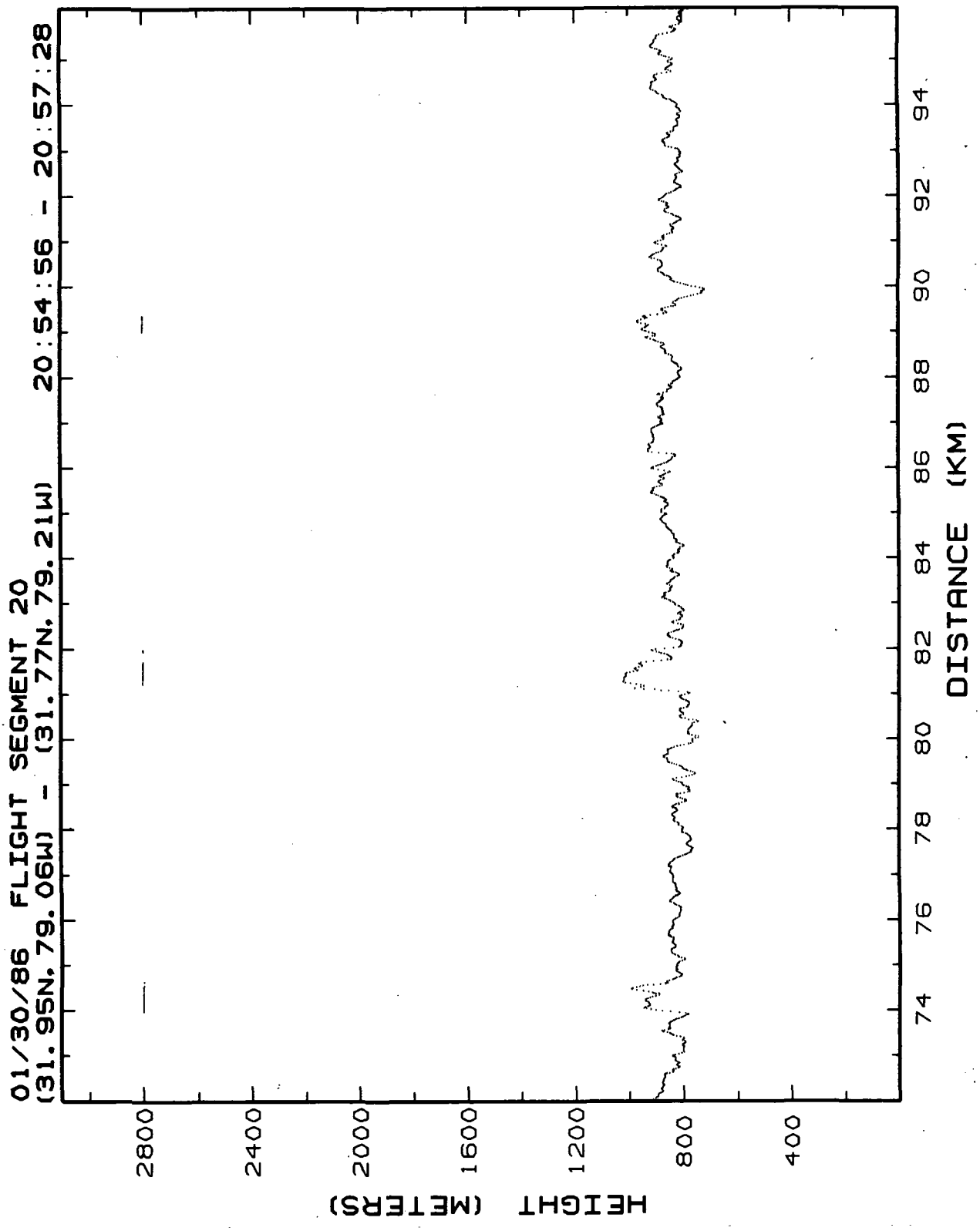

Figure 10.20d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 20, 72-96 km.

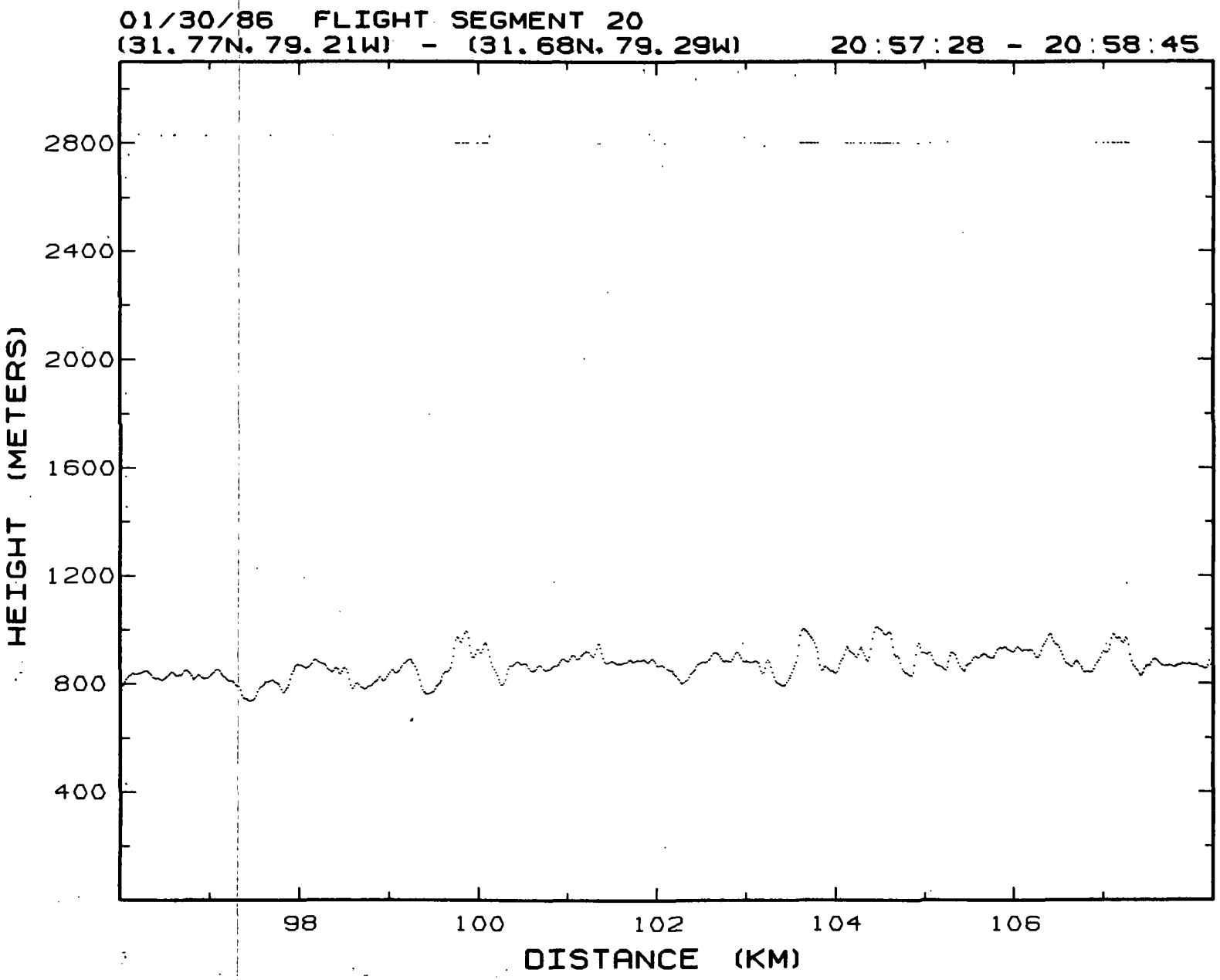

Figure 10.20e. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 20, 96-108 km.

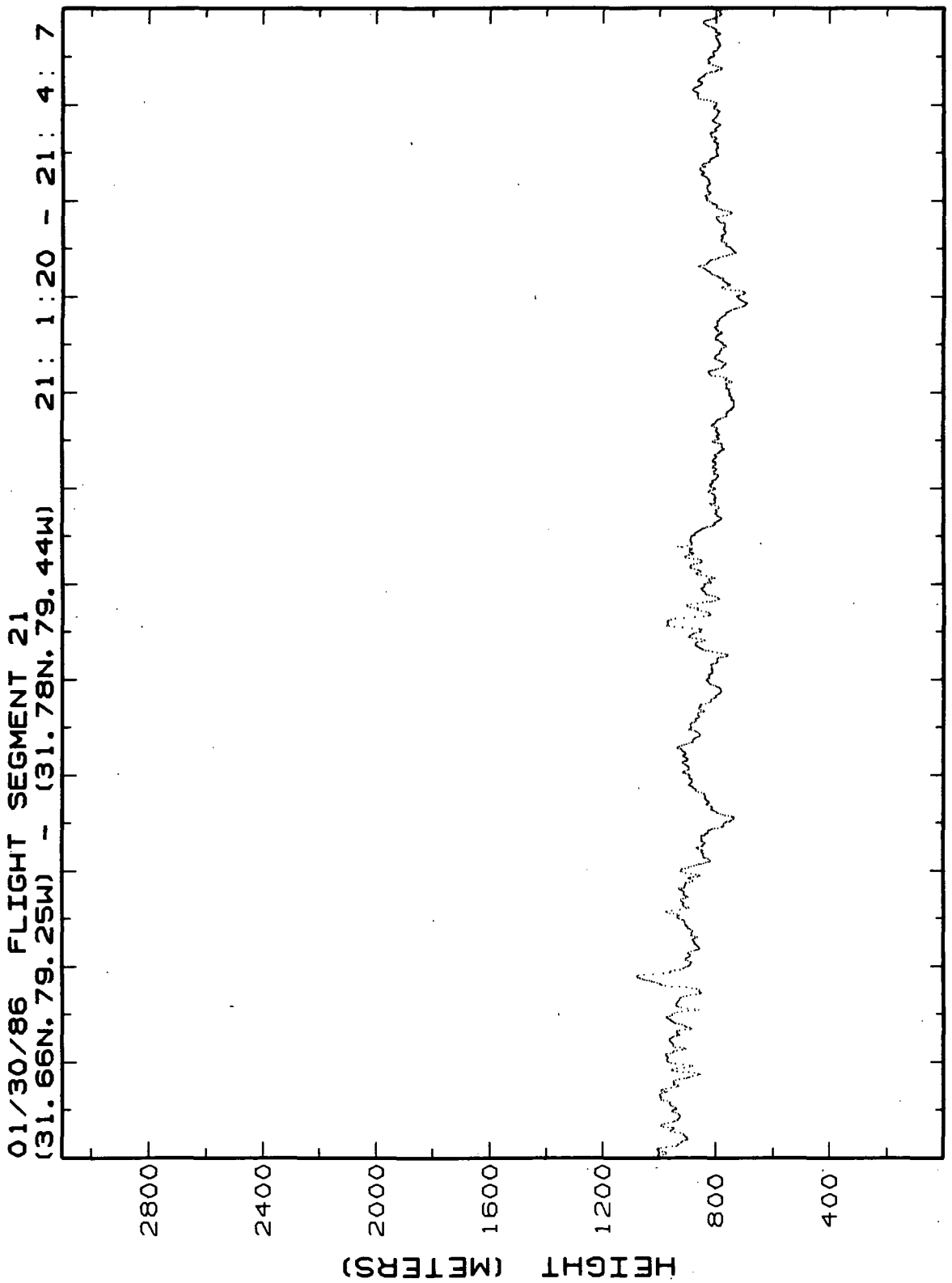

Figure 10.21a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 21, 0-24 km.

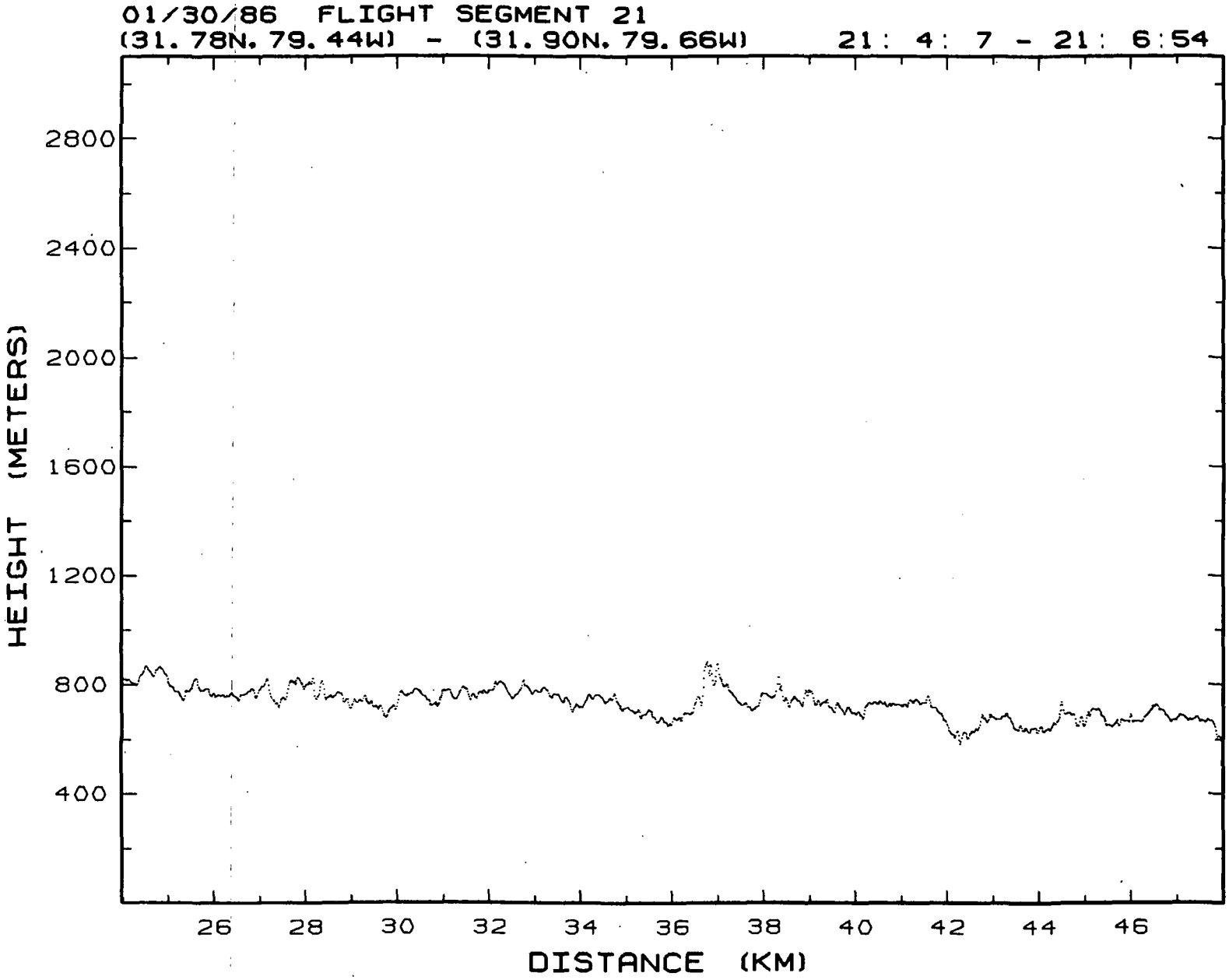

Figure 10.21b. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 21, 24-48 km.

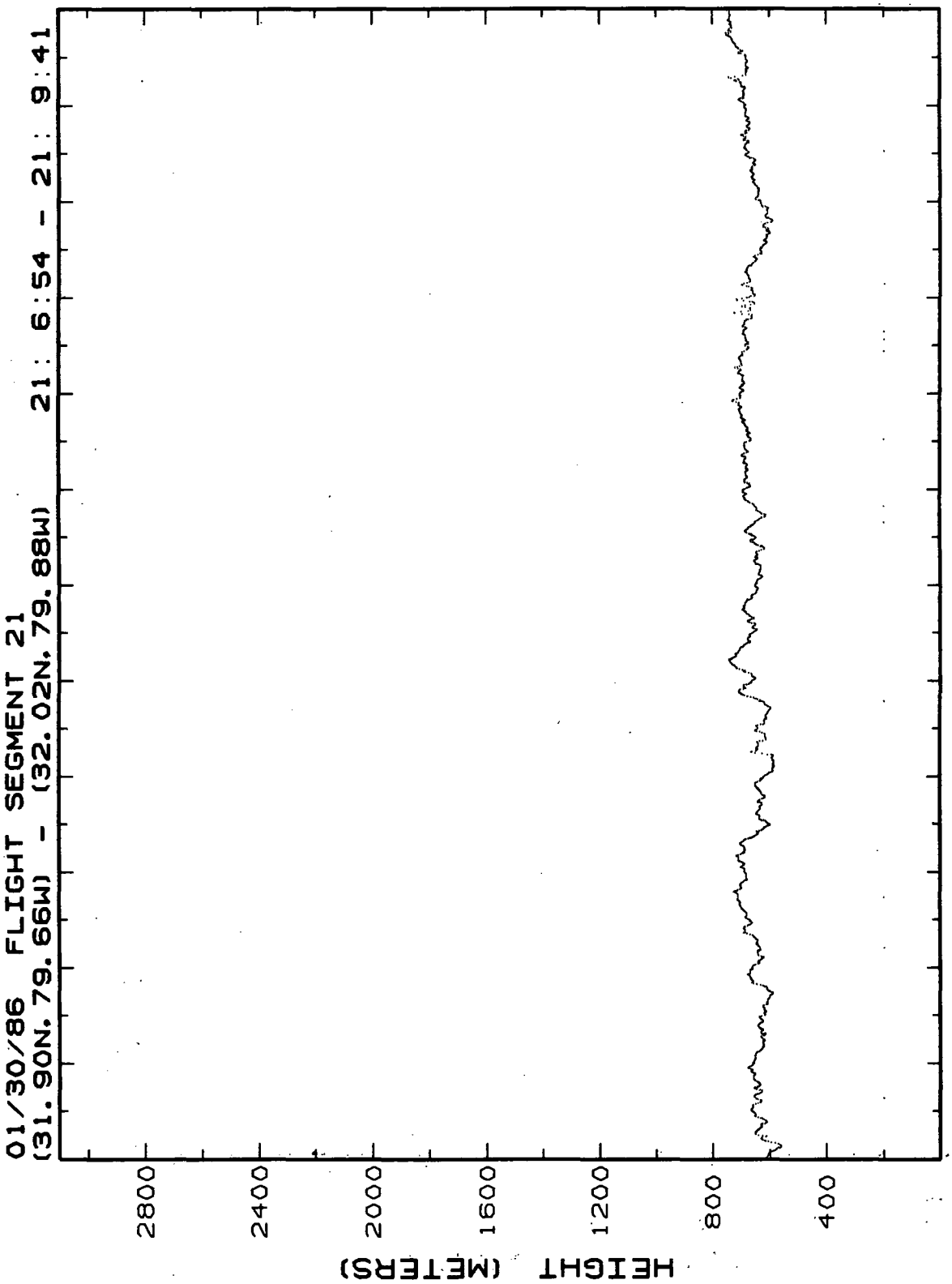

Figure 10.21c. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 21, 48-72 km.

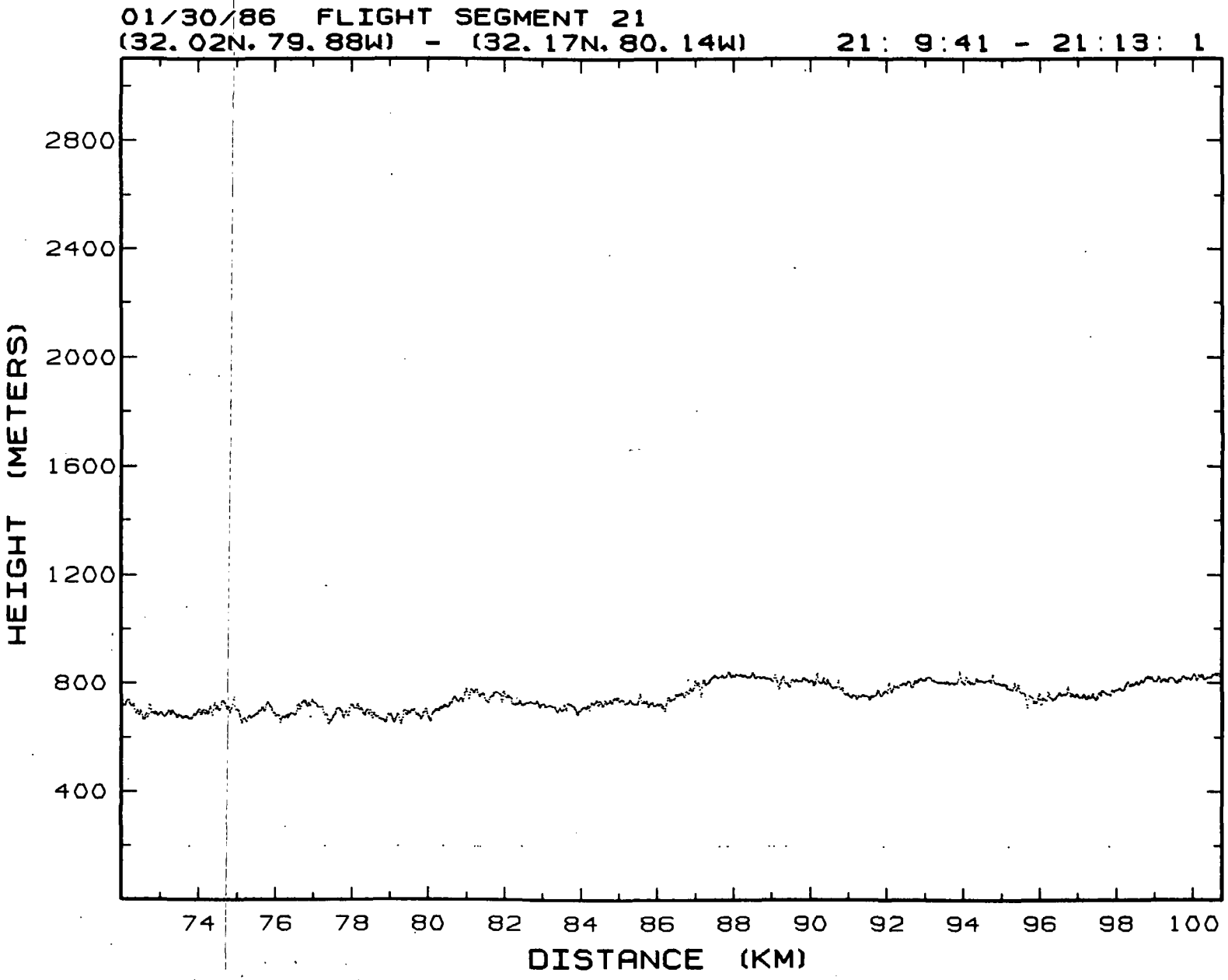

Figure 10.21d. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 21, 72-101 km.

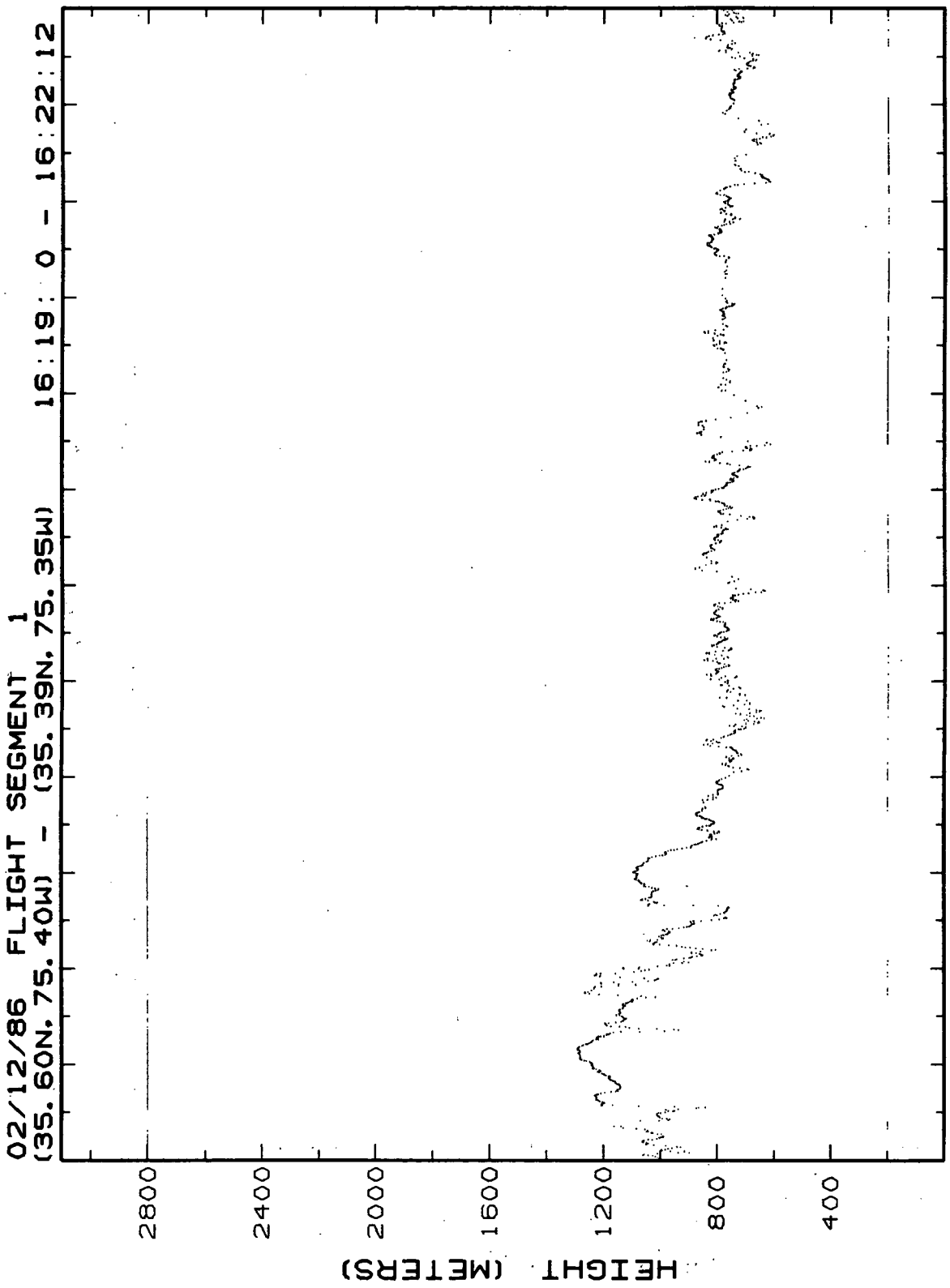

Figure 11.1a. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 1, 0-24 km.

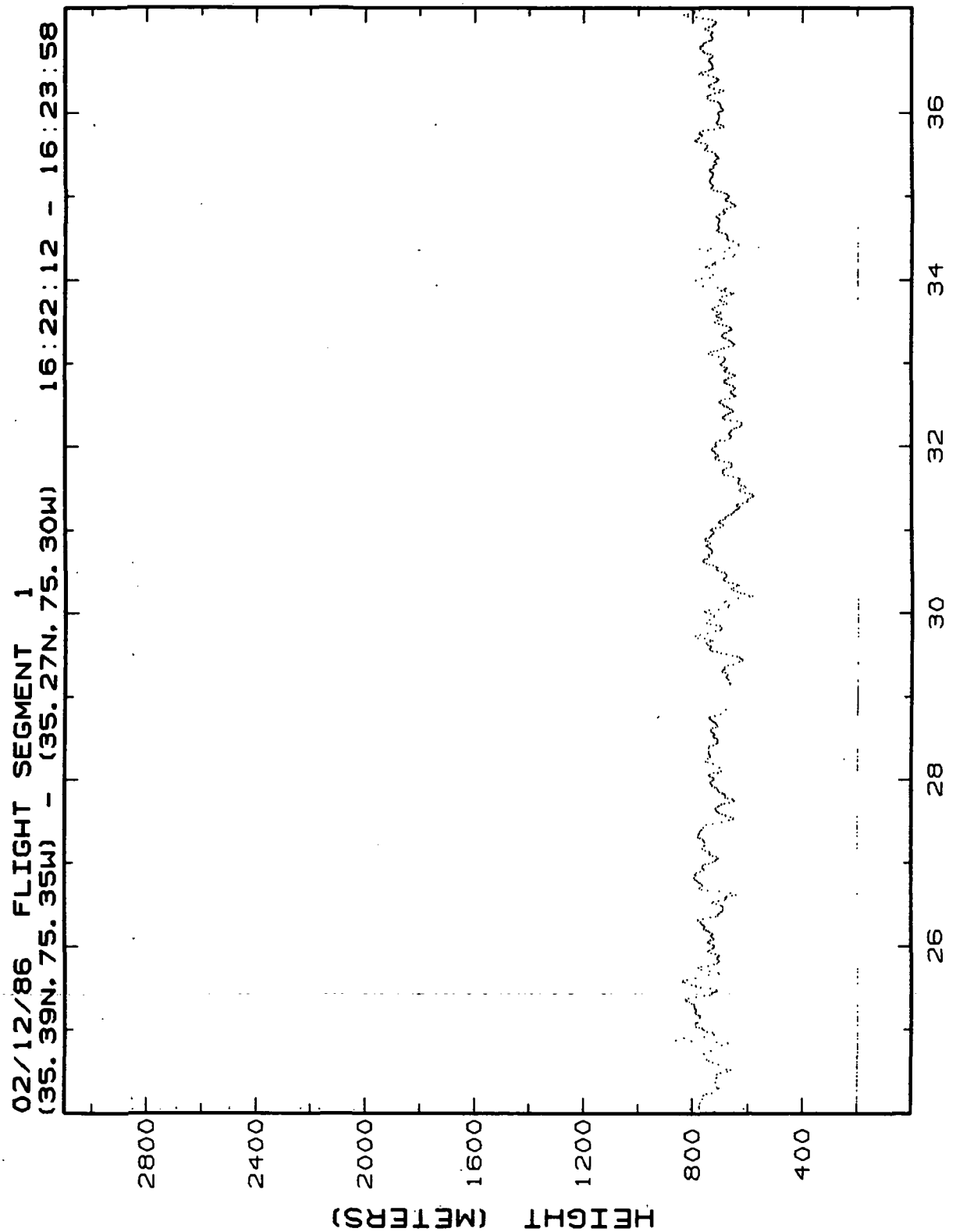

Figure 11.1b: Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 1, 24-37 km.

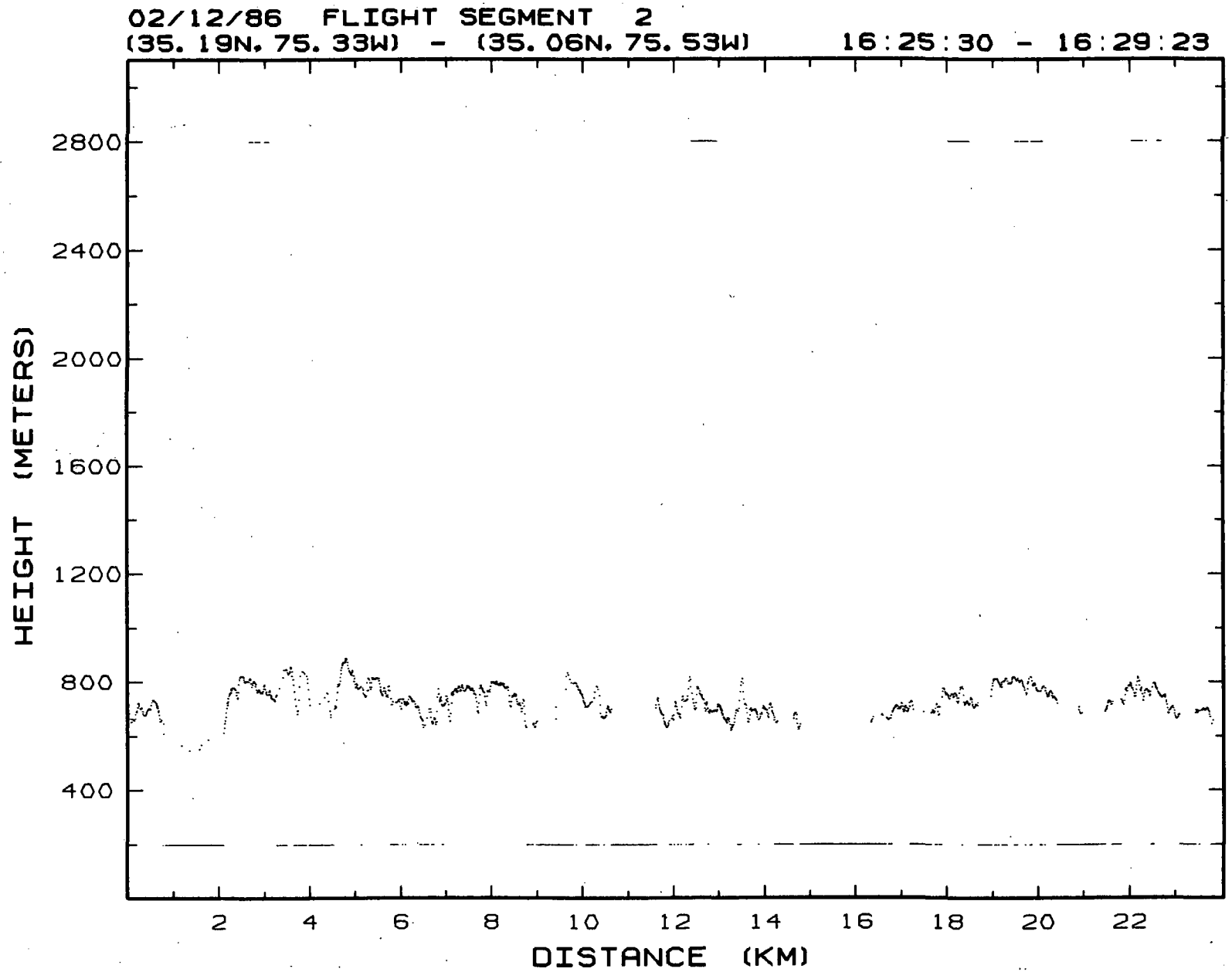

Figure 11.2a. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 2, 0-24 km.

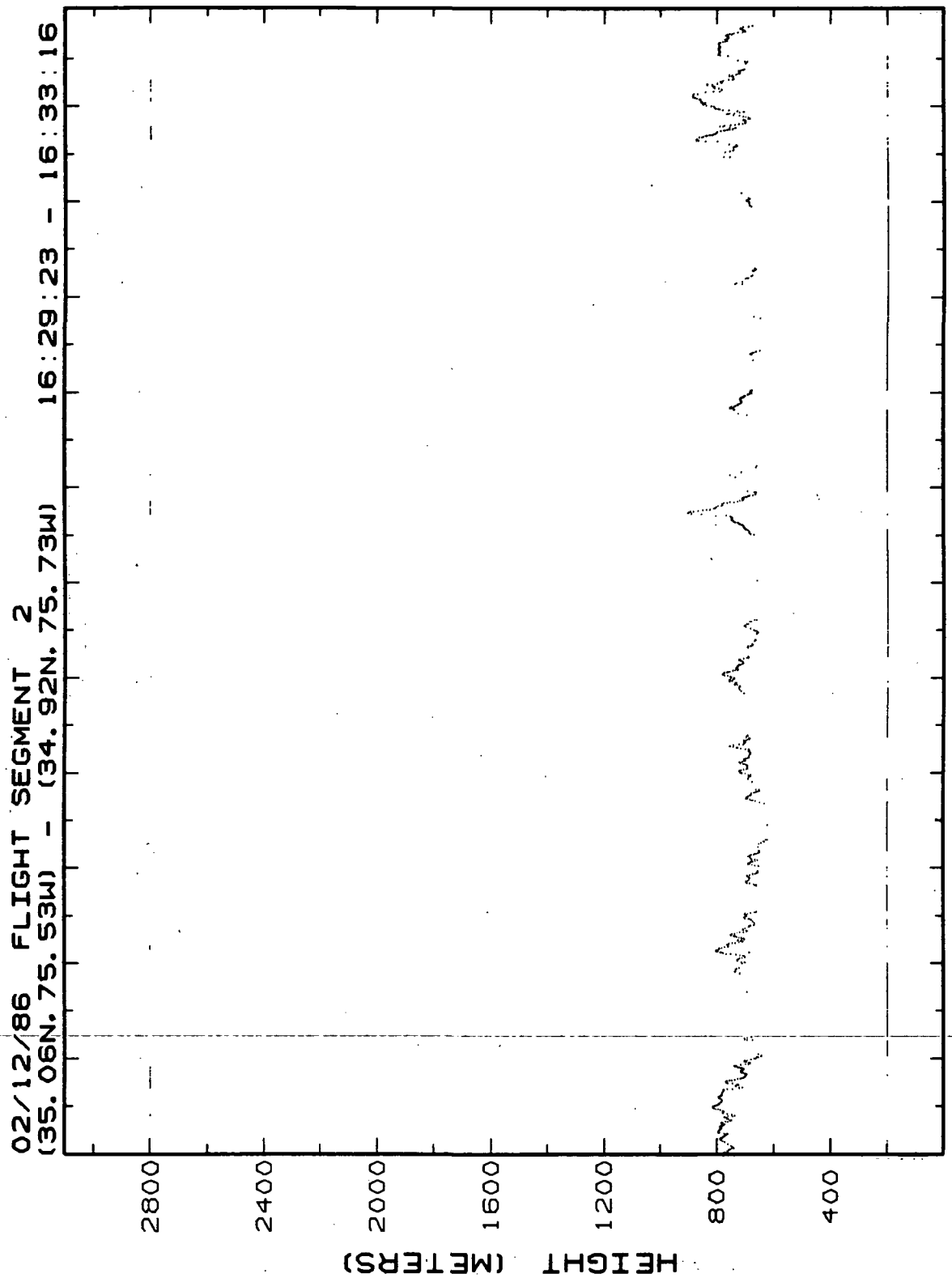

Figure 11.2b. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 2, 24-48 km.

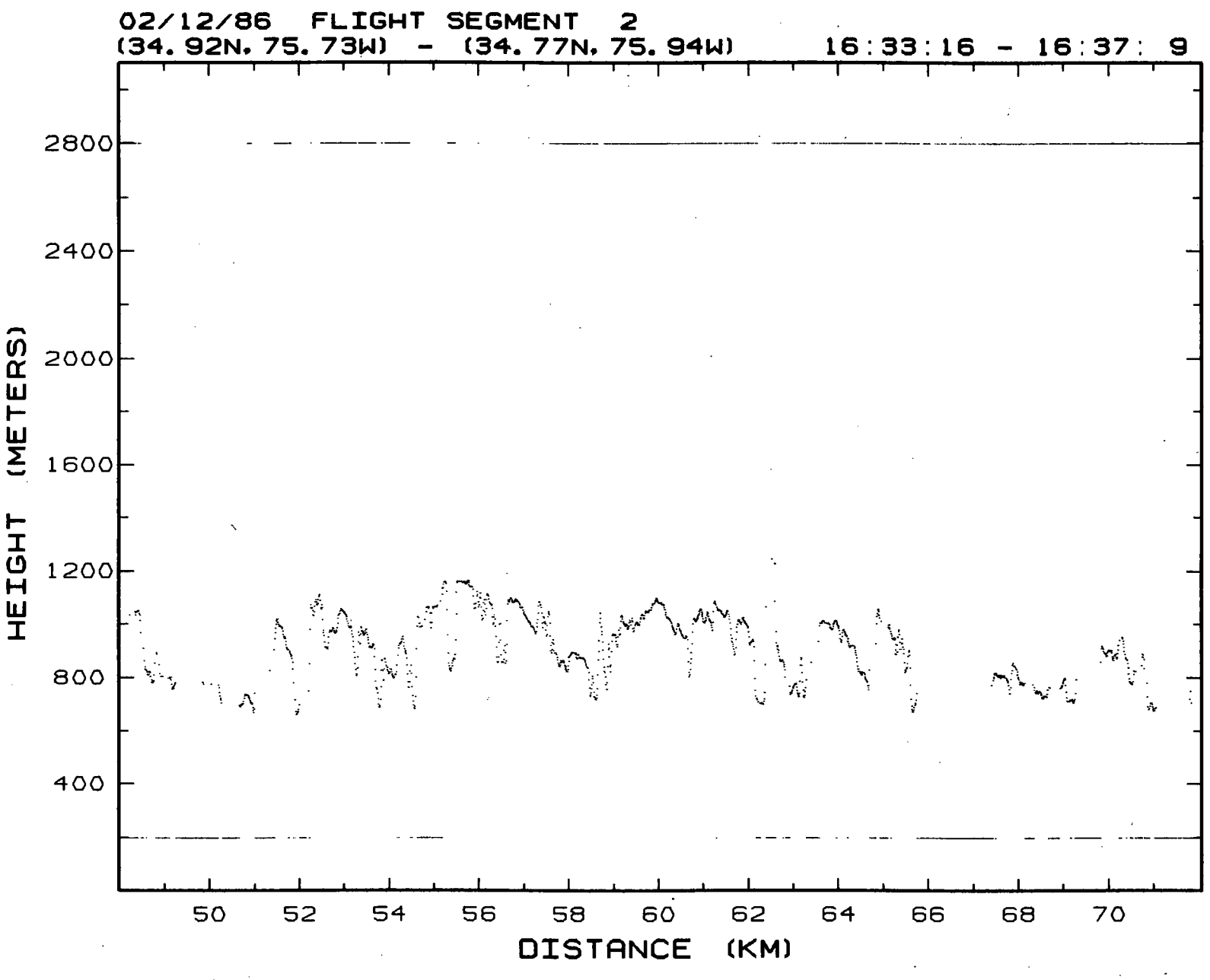

Figure 11.2c. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 2, 48-72 km.

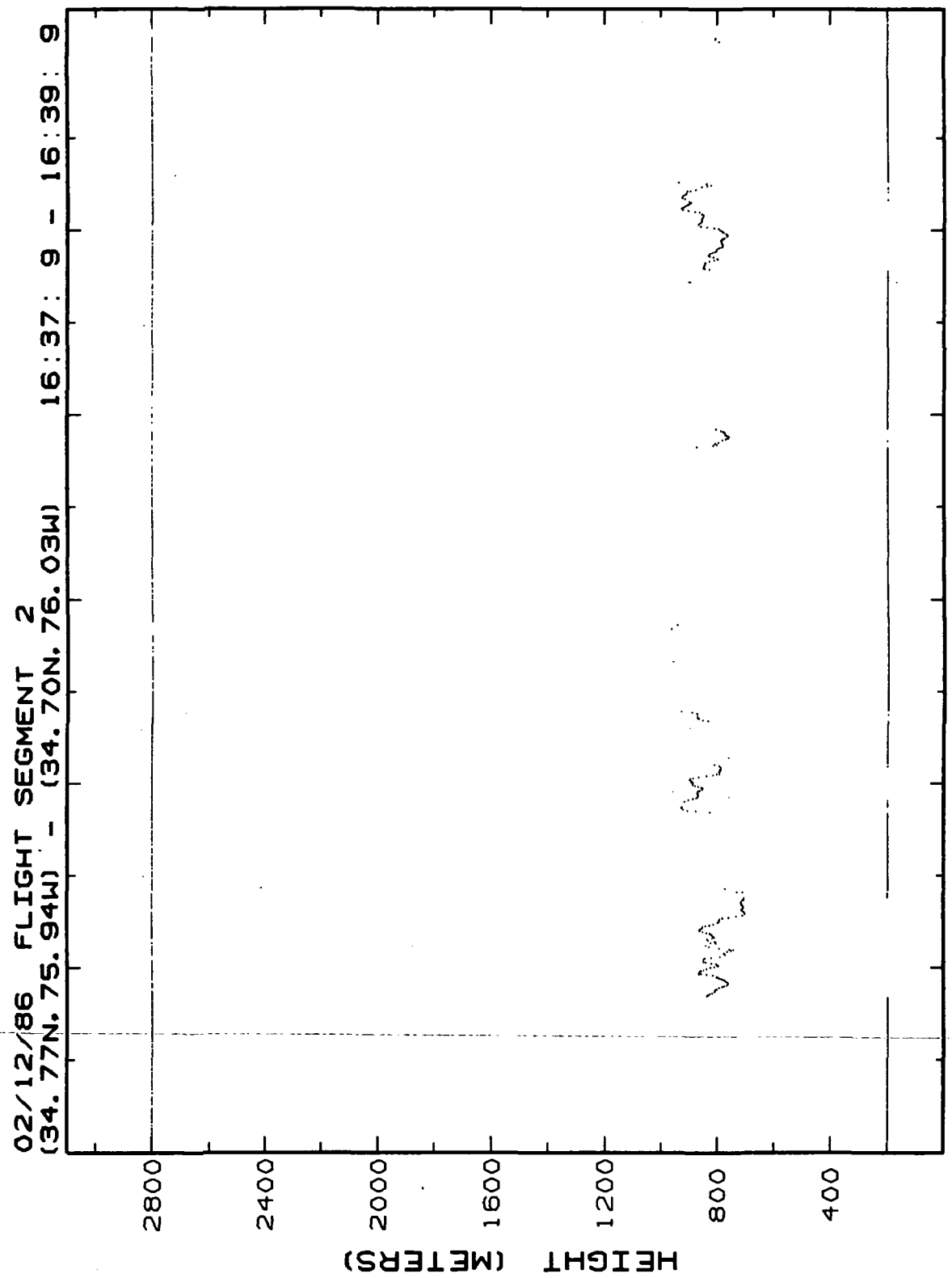

Figure 11.2d. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 2, 72-84 km.

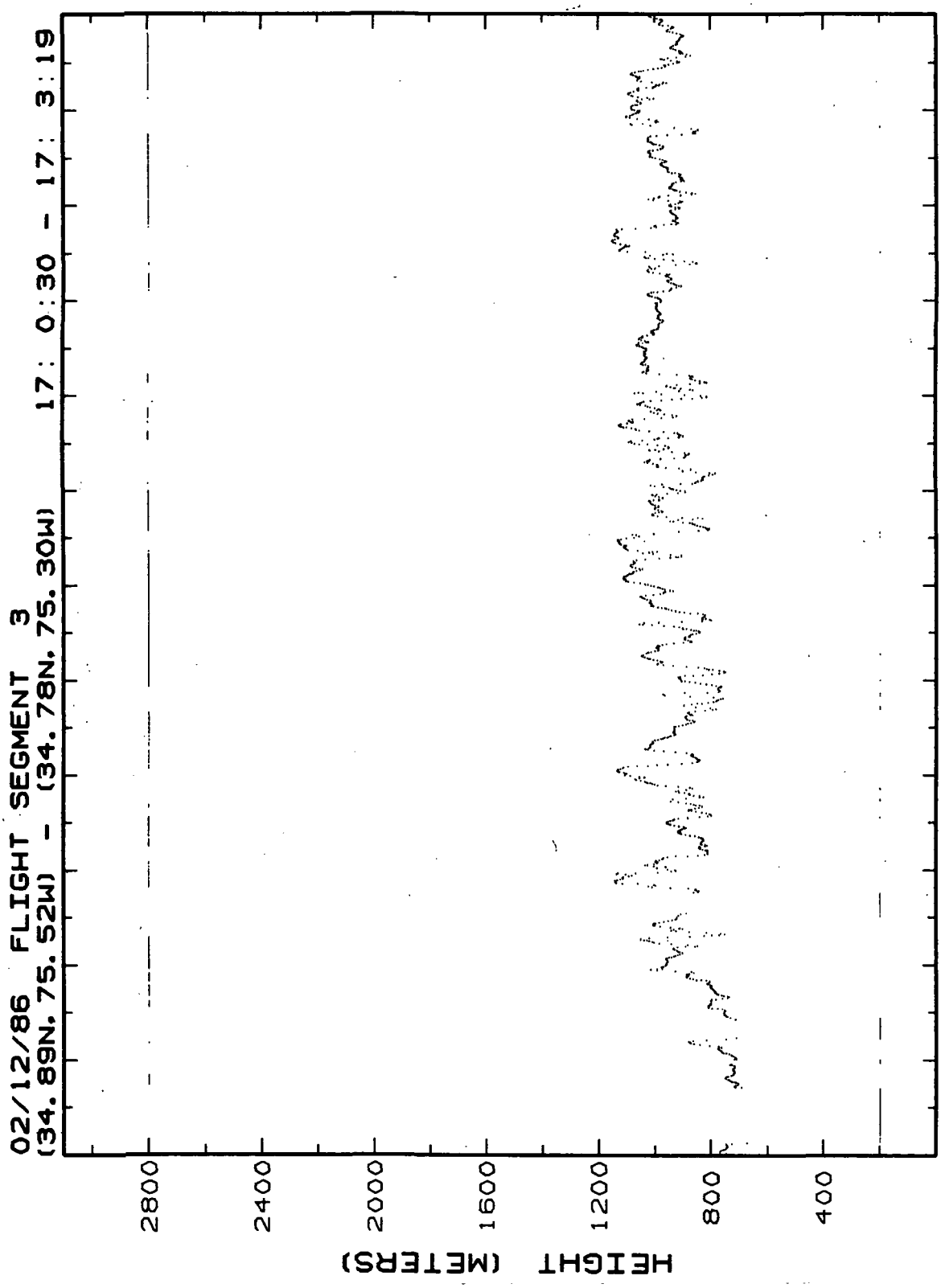

Figure 11.3a. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 3, 0-24 km.

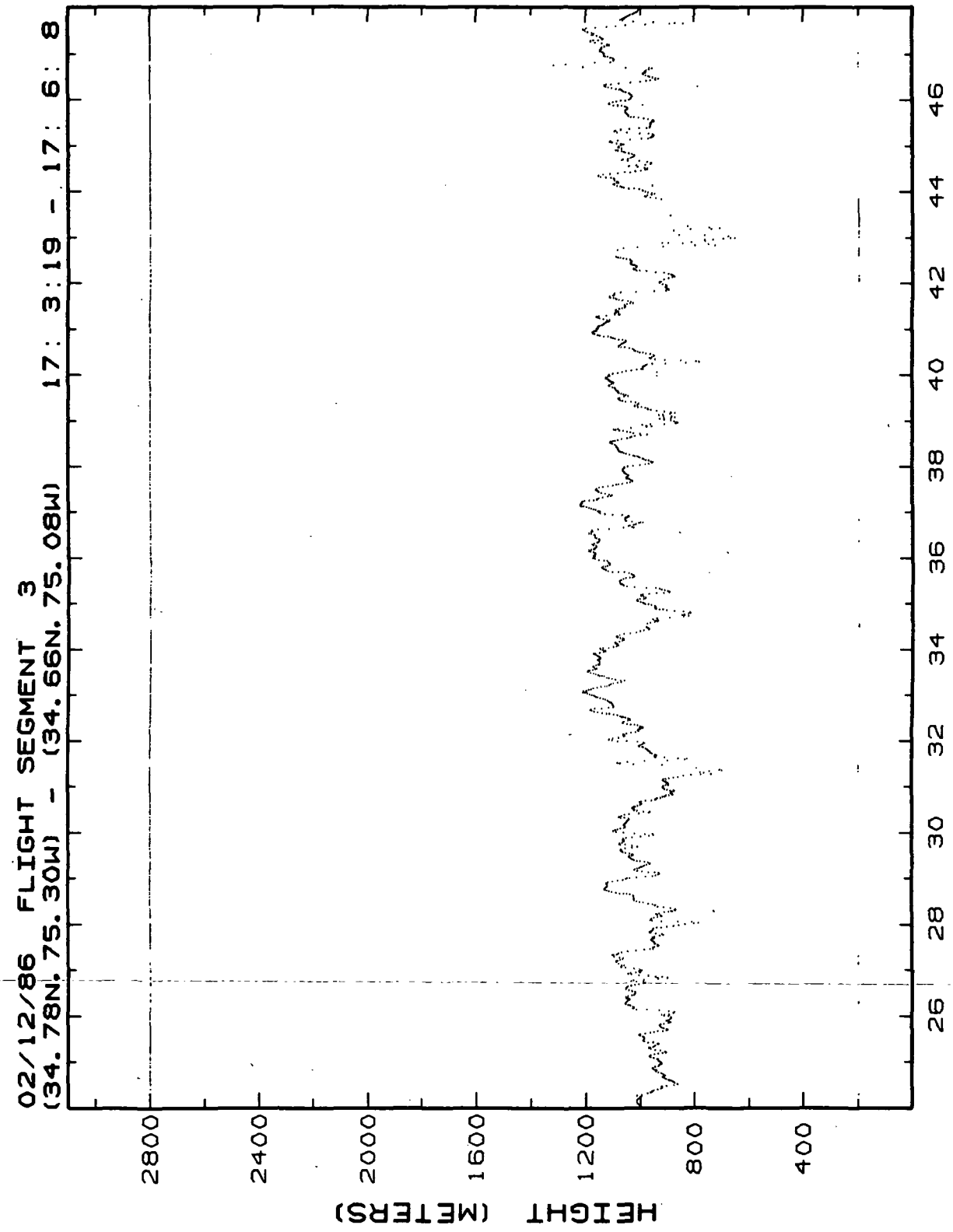

Figure 11.3b. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 3, 24-48 km.

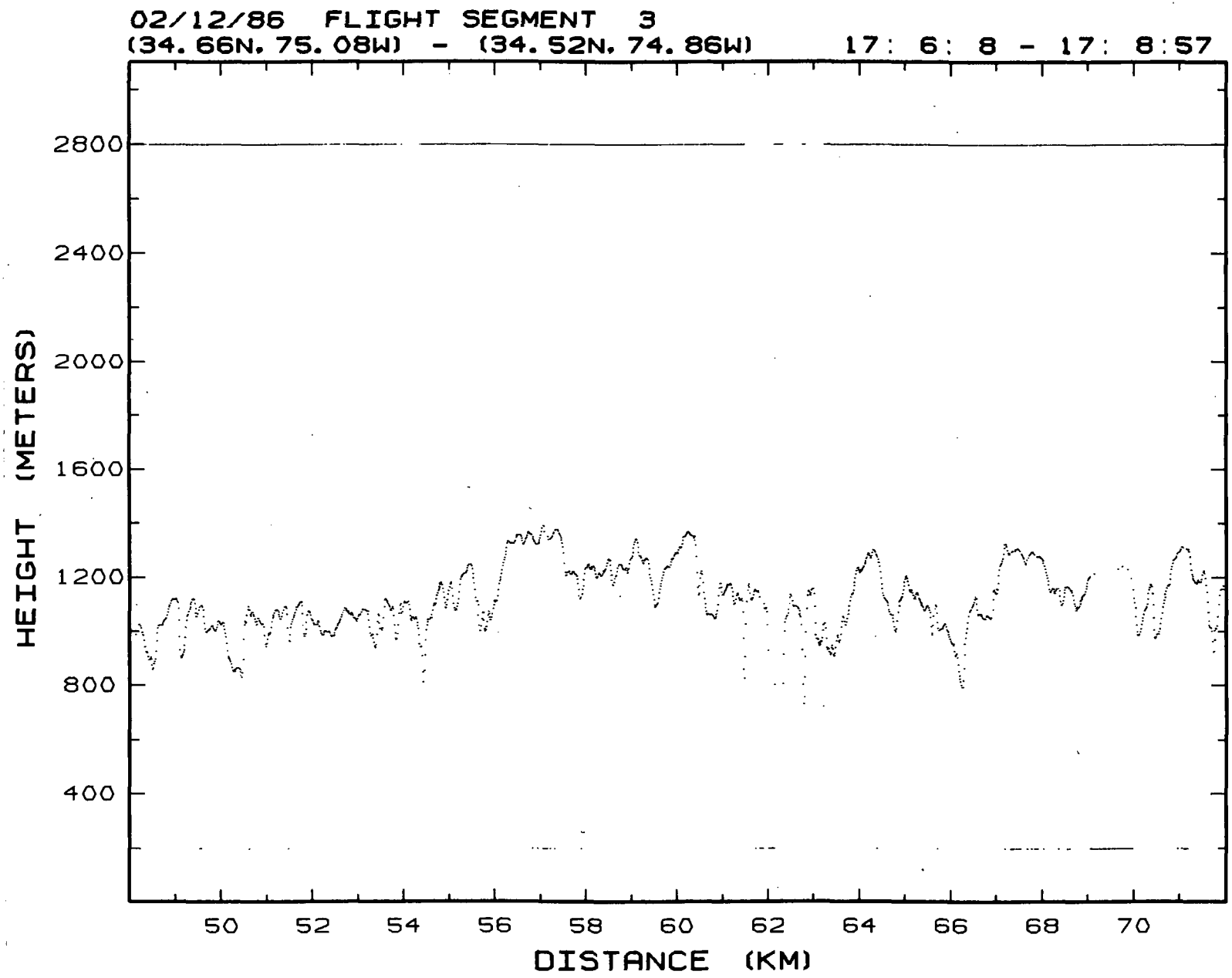

Figure 11.3c. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 3, 48-72 km.

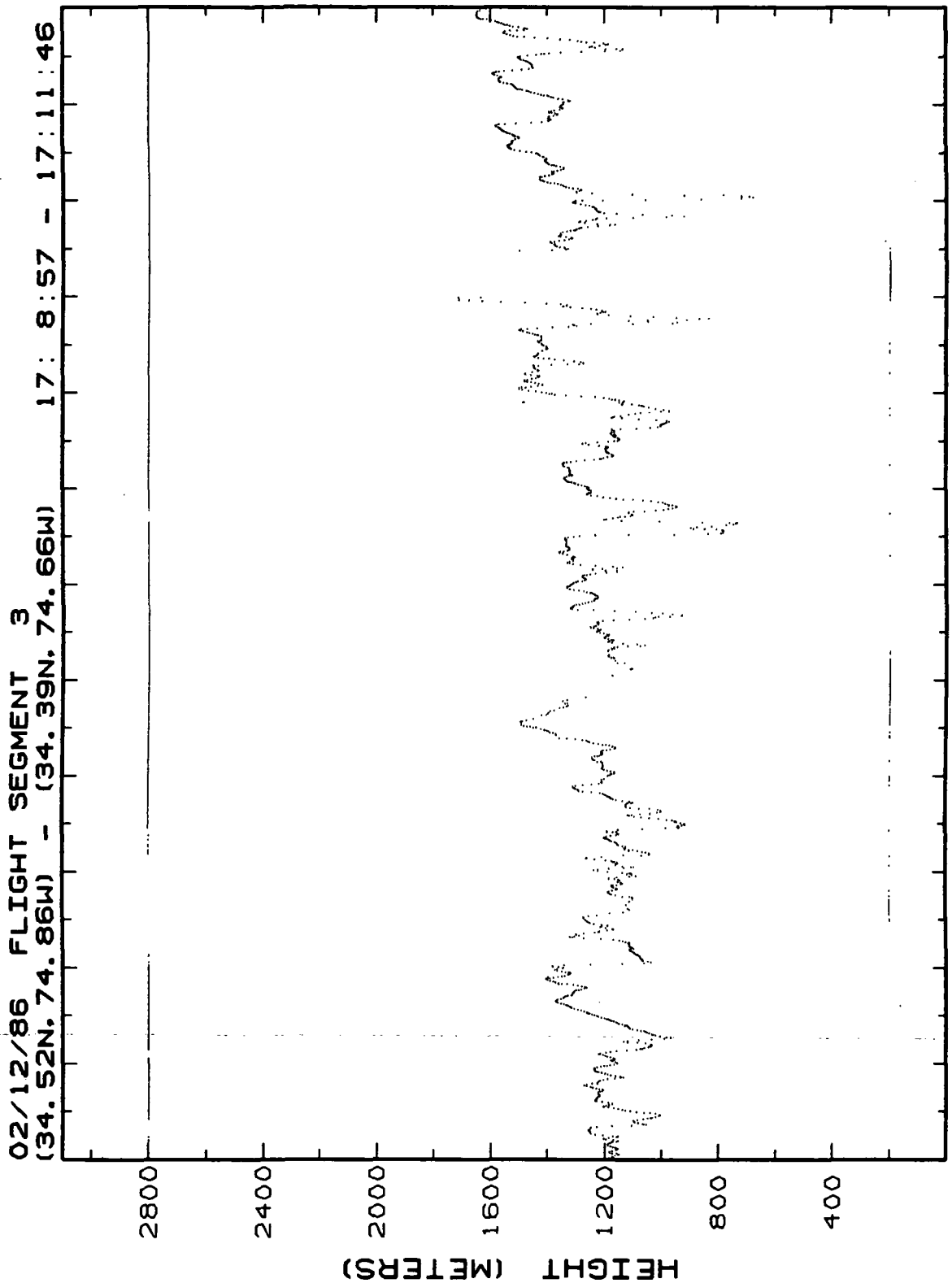

Figure 11.3d. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 3, 72-96 km.

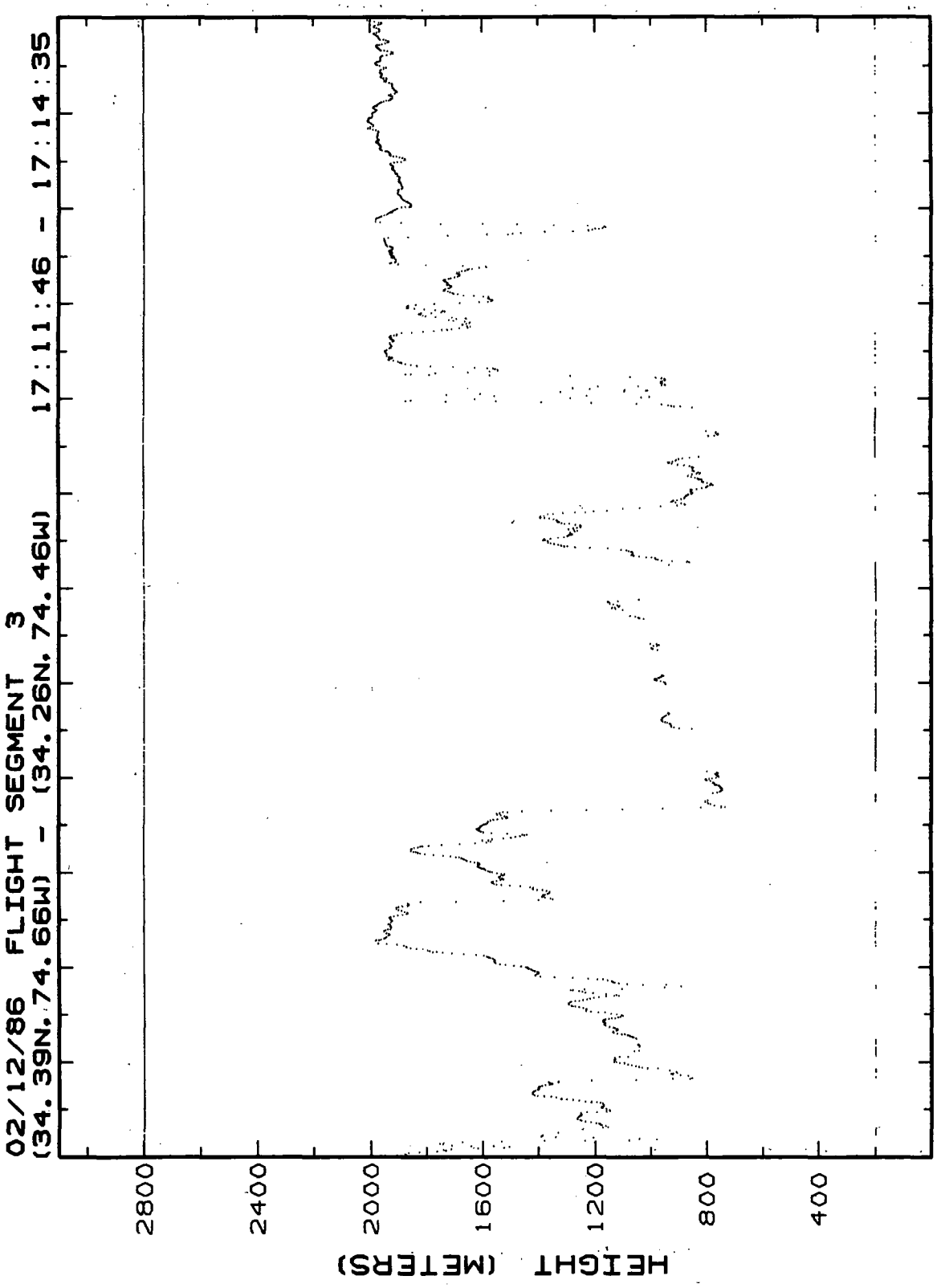

Figure 11.3e. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 3, 96-120 km.

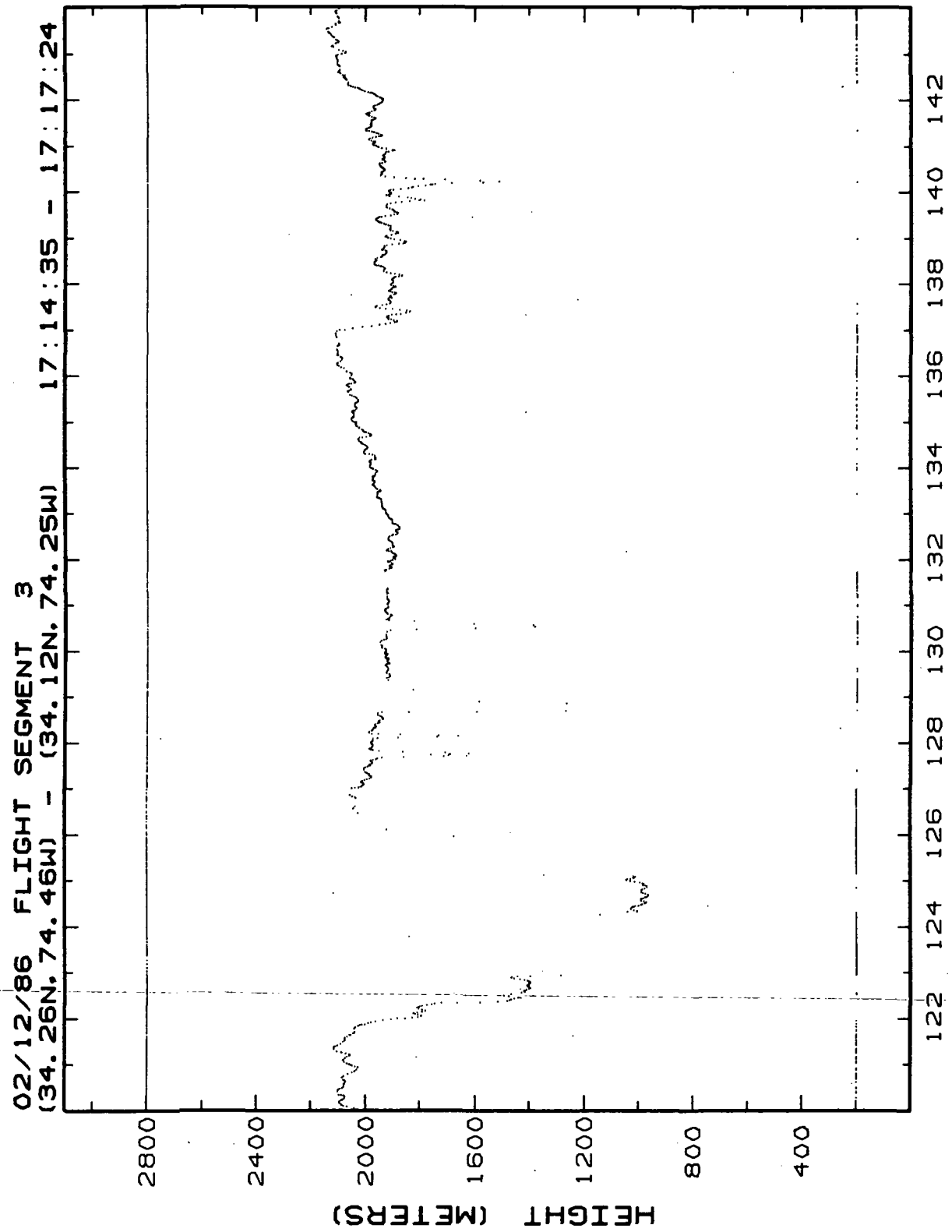

Figure 11.3f. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 3, 120-144 km.

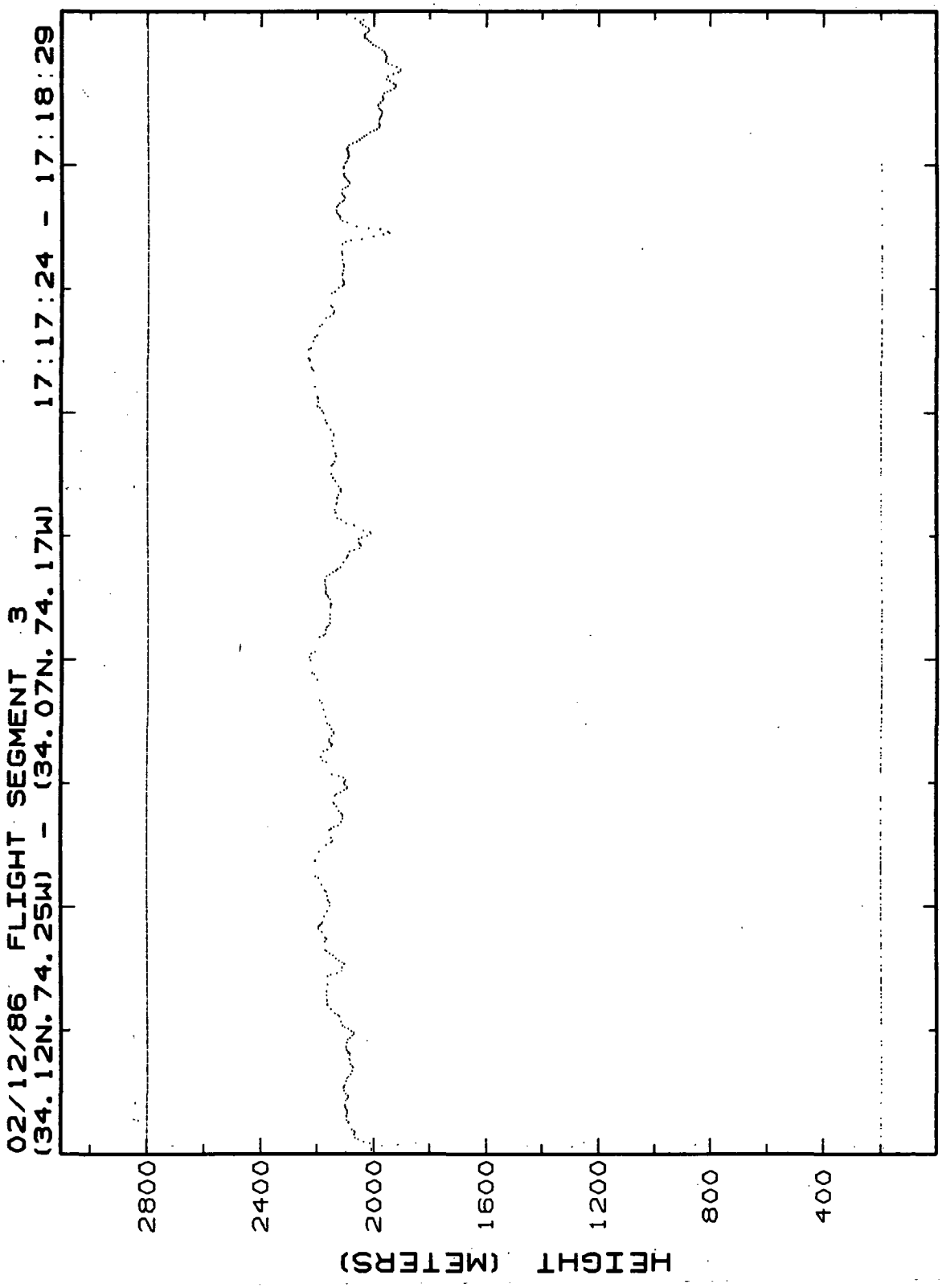

Figure 11.3g. Lidar retrieved MABL heights for Flight 3, 12-Feb-86, flight segment 3, 144-153 km.

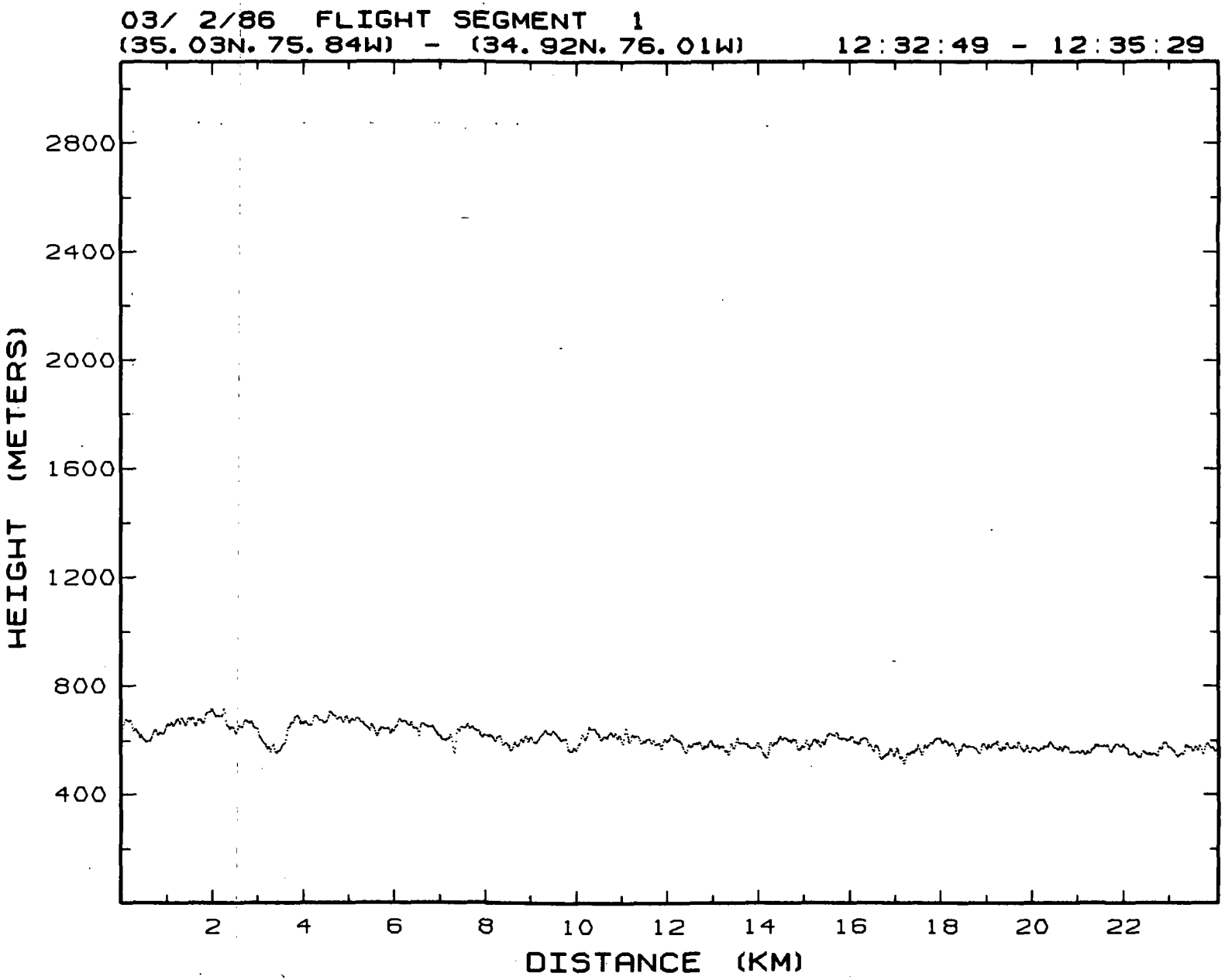

Figure 12.1a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 1, 0-24 km.

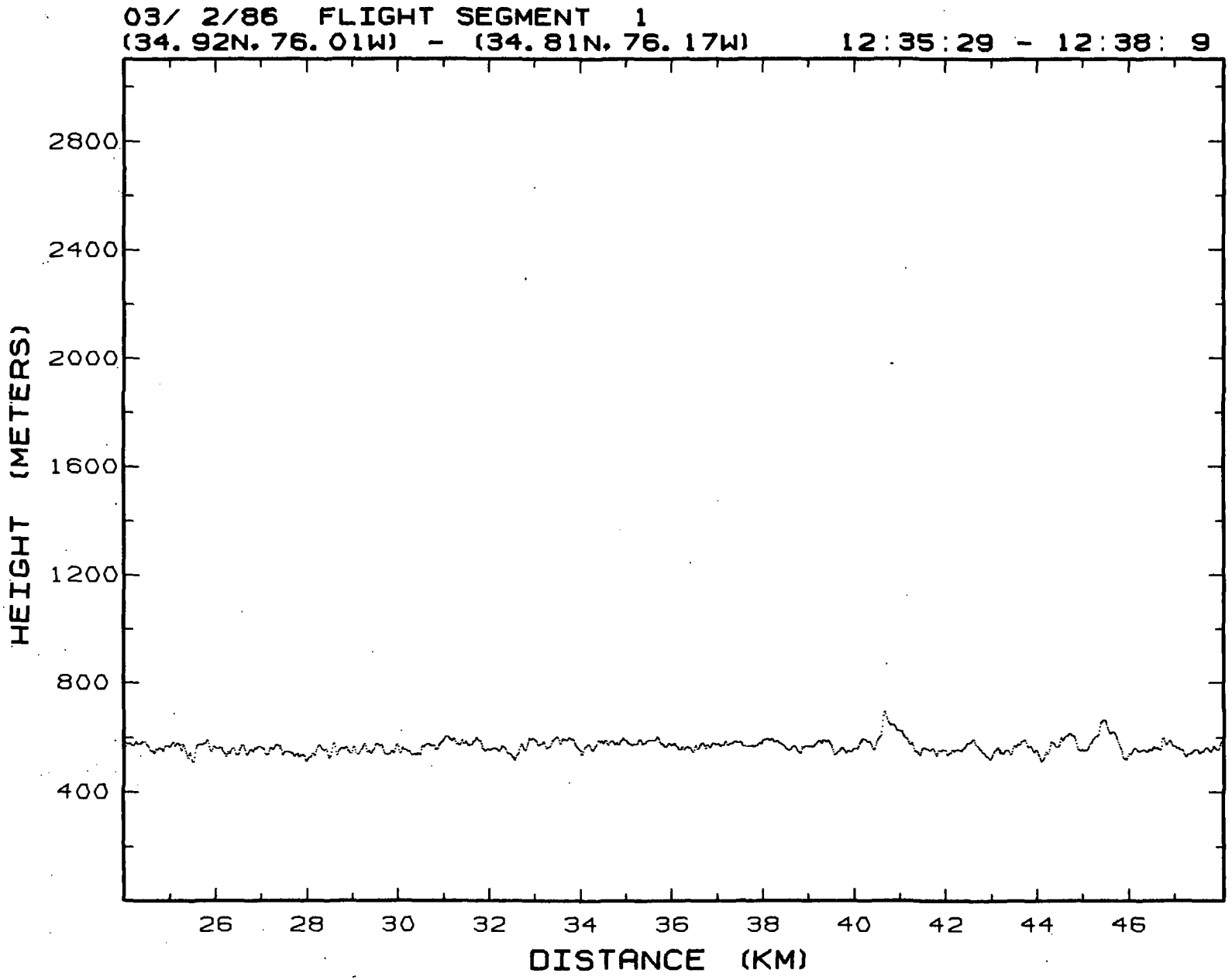

Figure 12.1b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 1, 24-48 km.

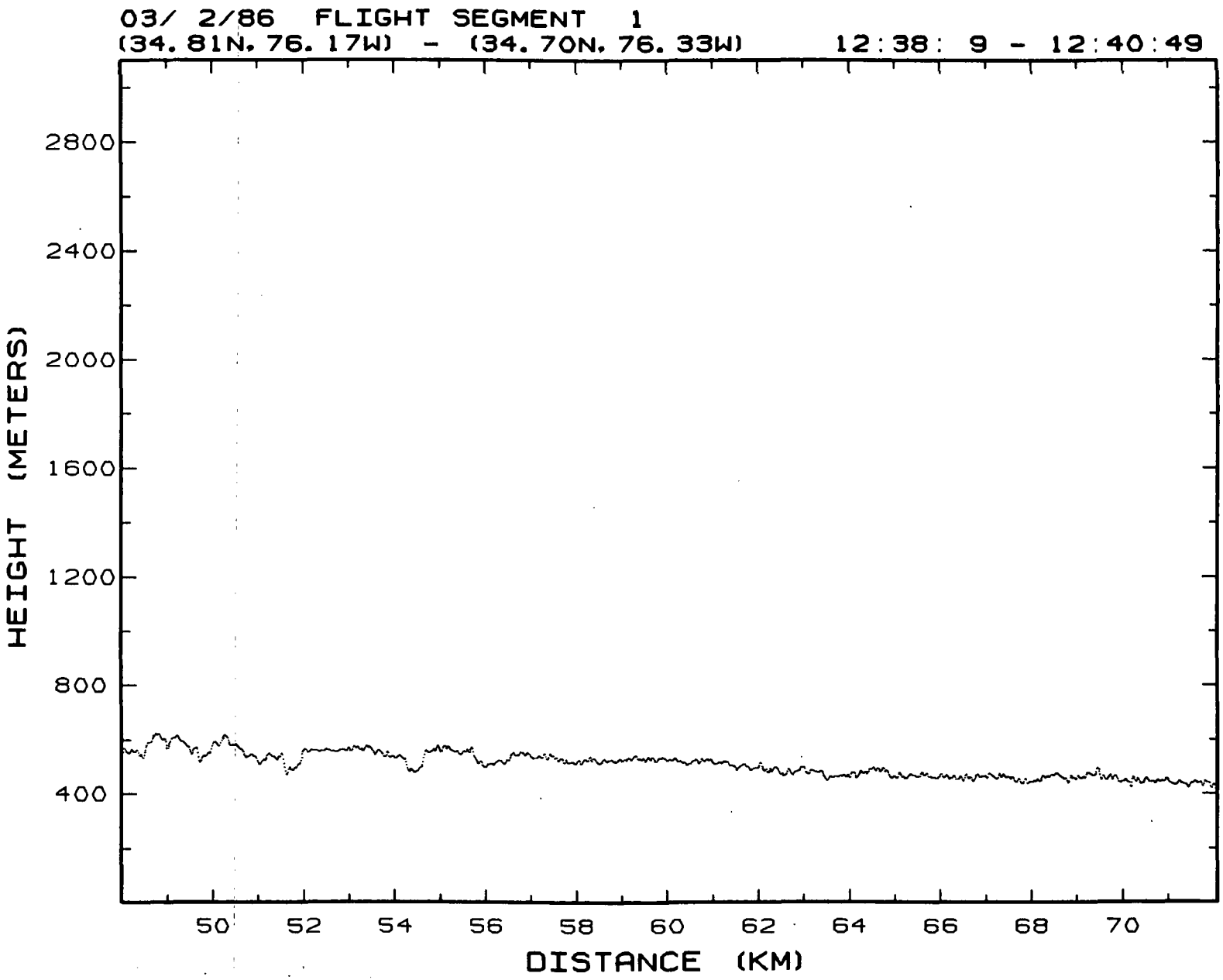

Figure 12.1c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 1, 48-72 km.

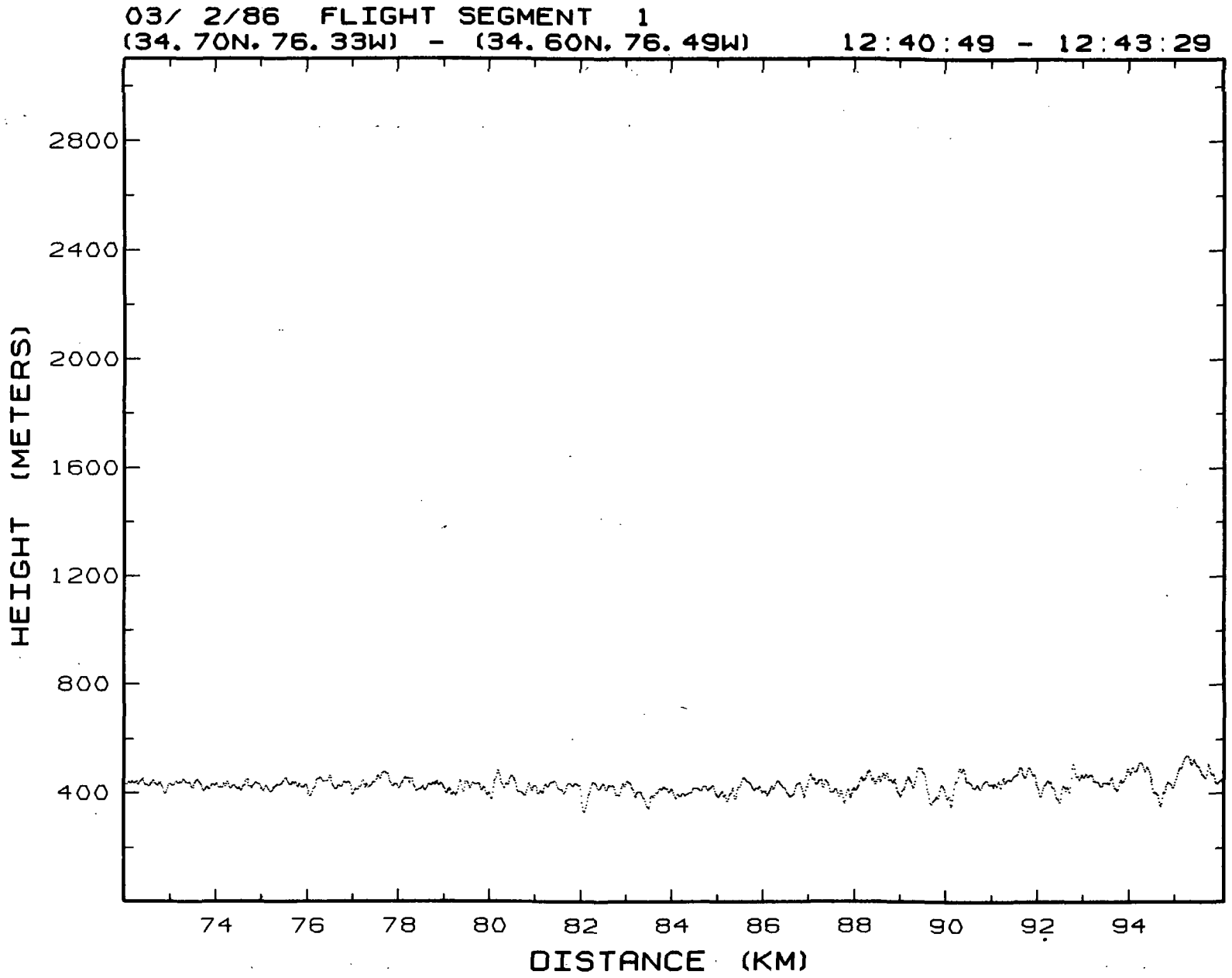

Figure 12.1d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 1, 72-96 km.

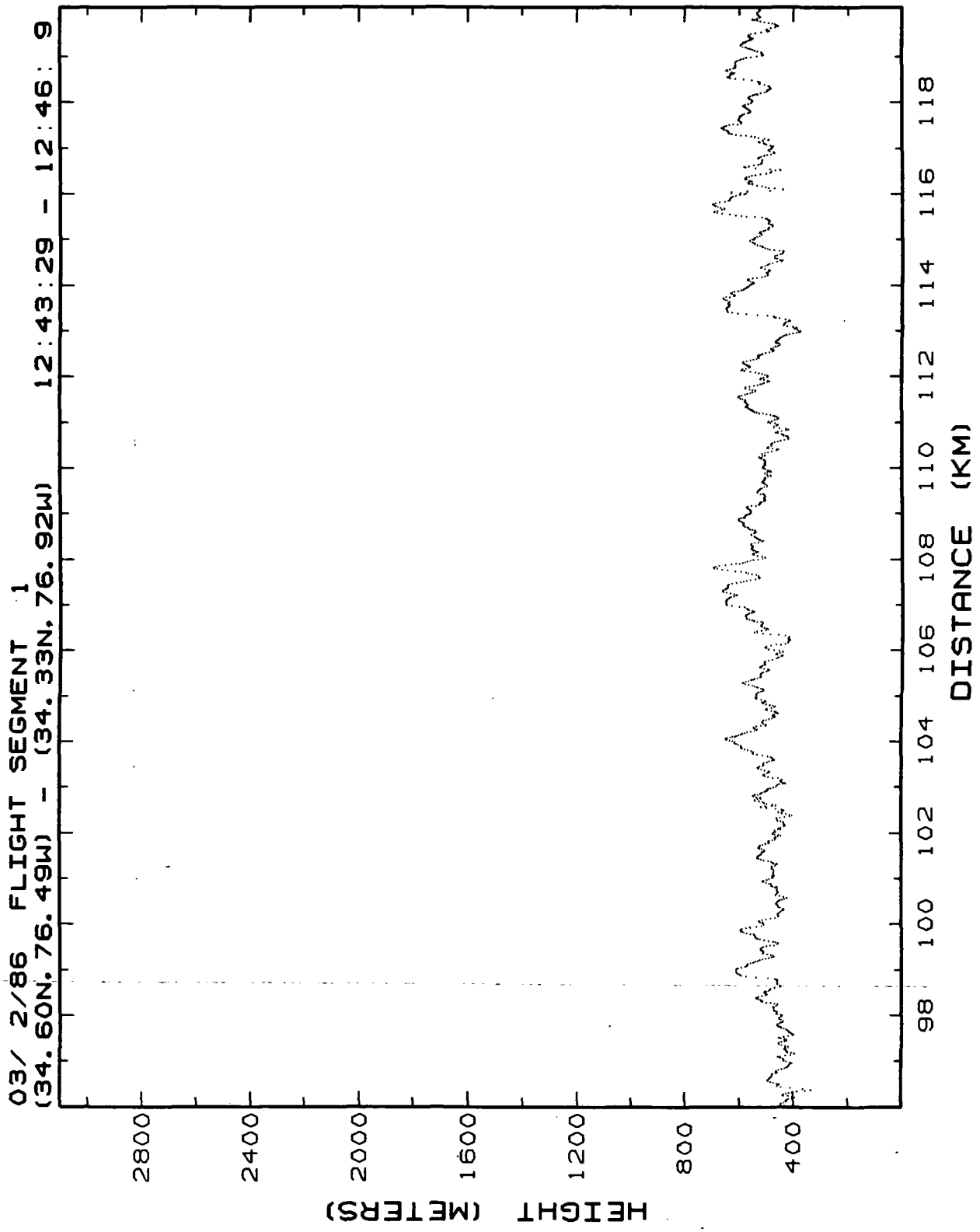

Figure 12.1e. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 1, 96-120 km.

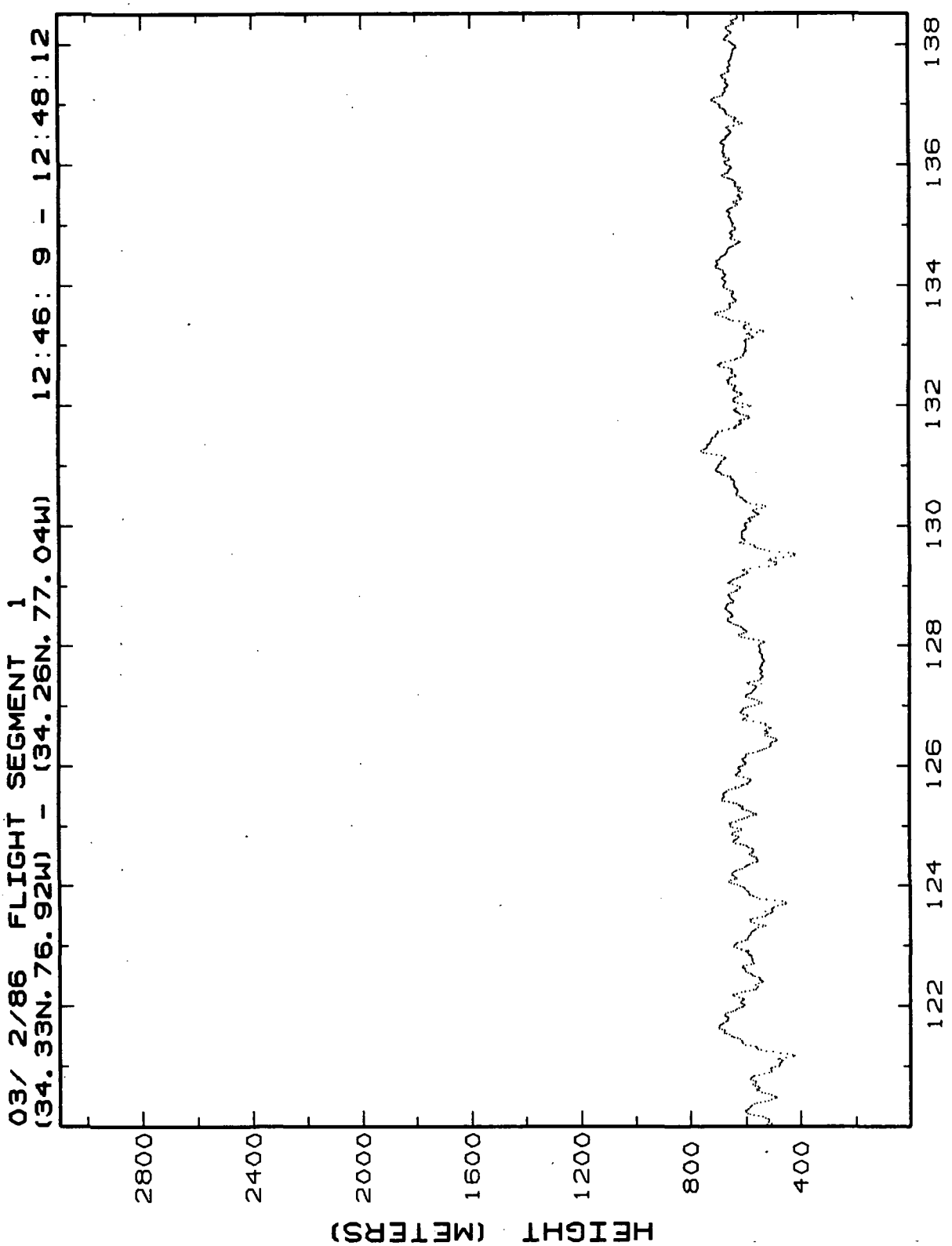

Figure 12.1f. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 1, 120-138 km.

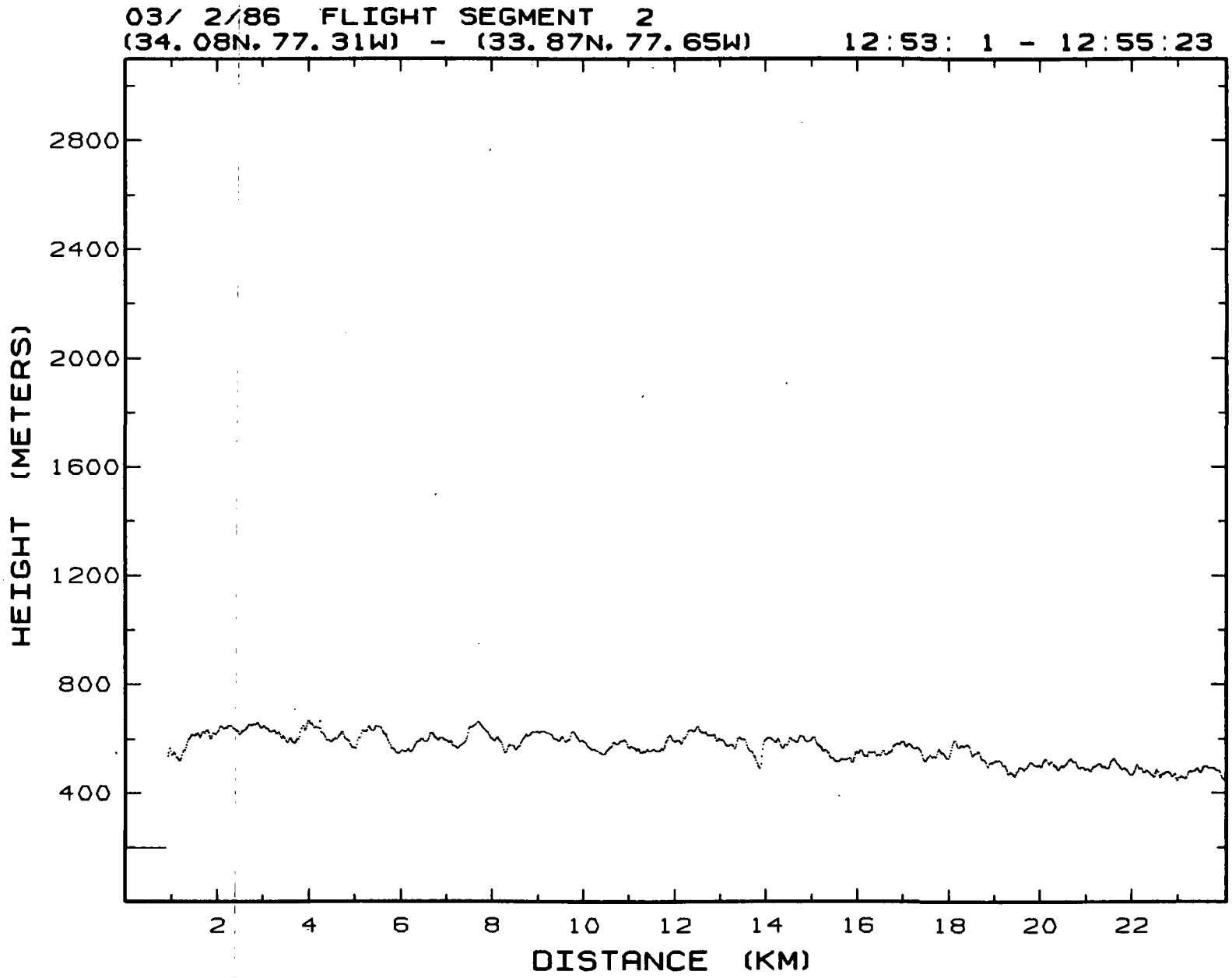

Figure 12.2a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 2, 0-24 km.

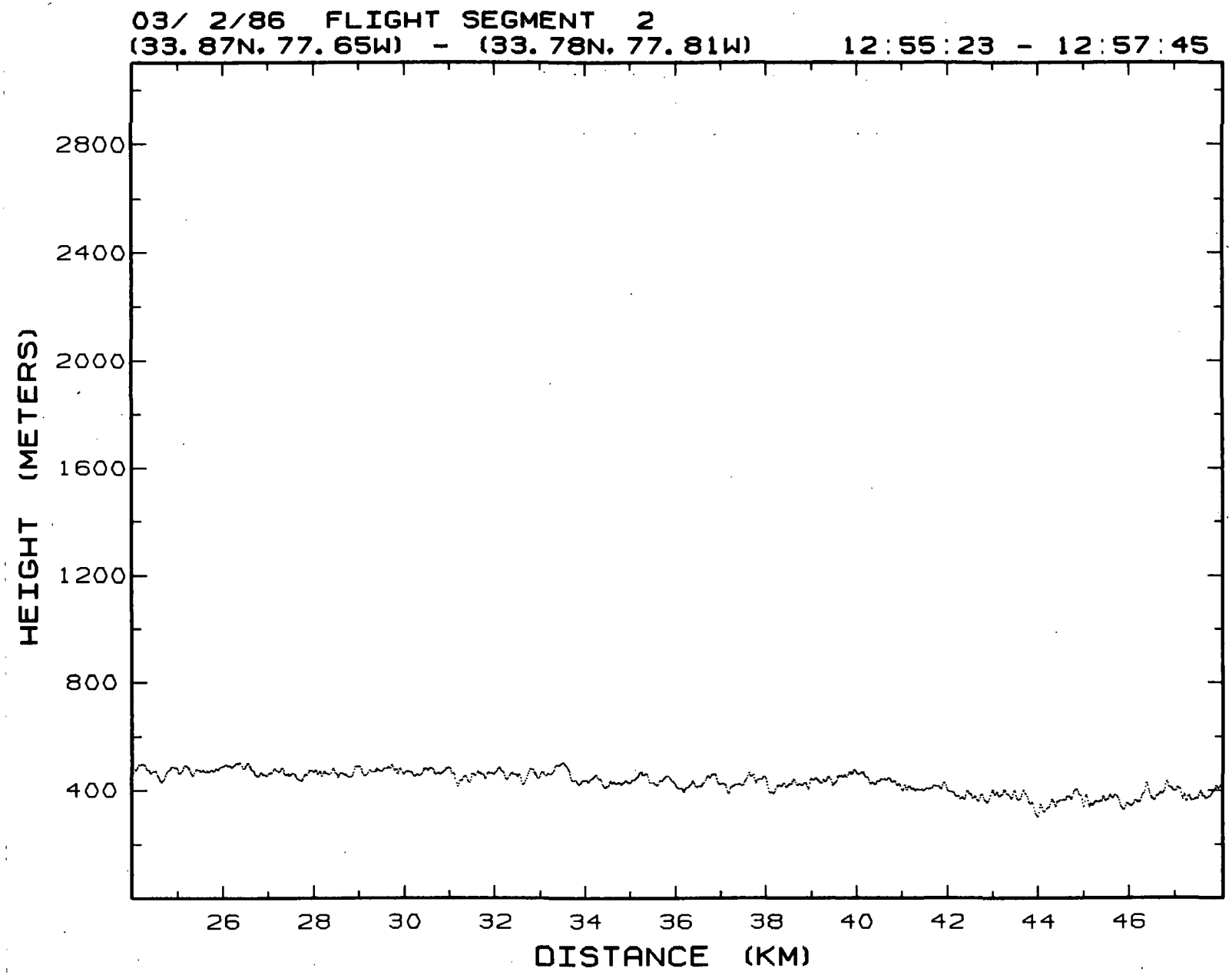

Figure 12.2b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 2, 24-48 km.

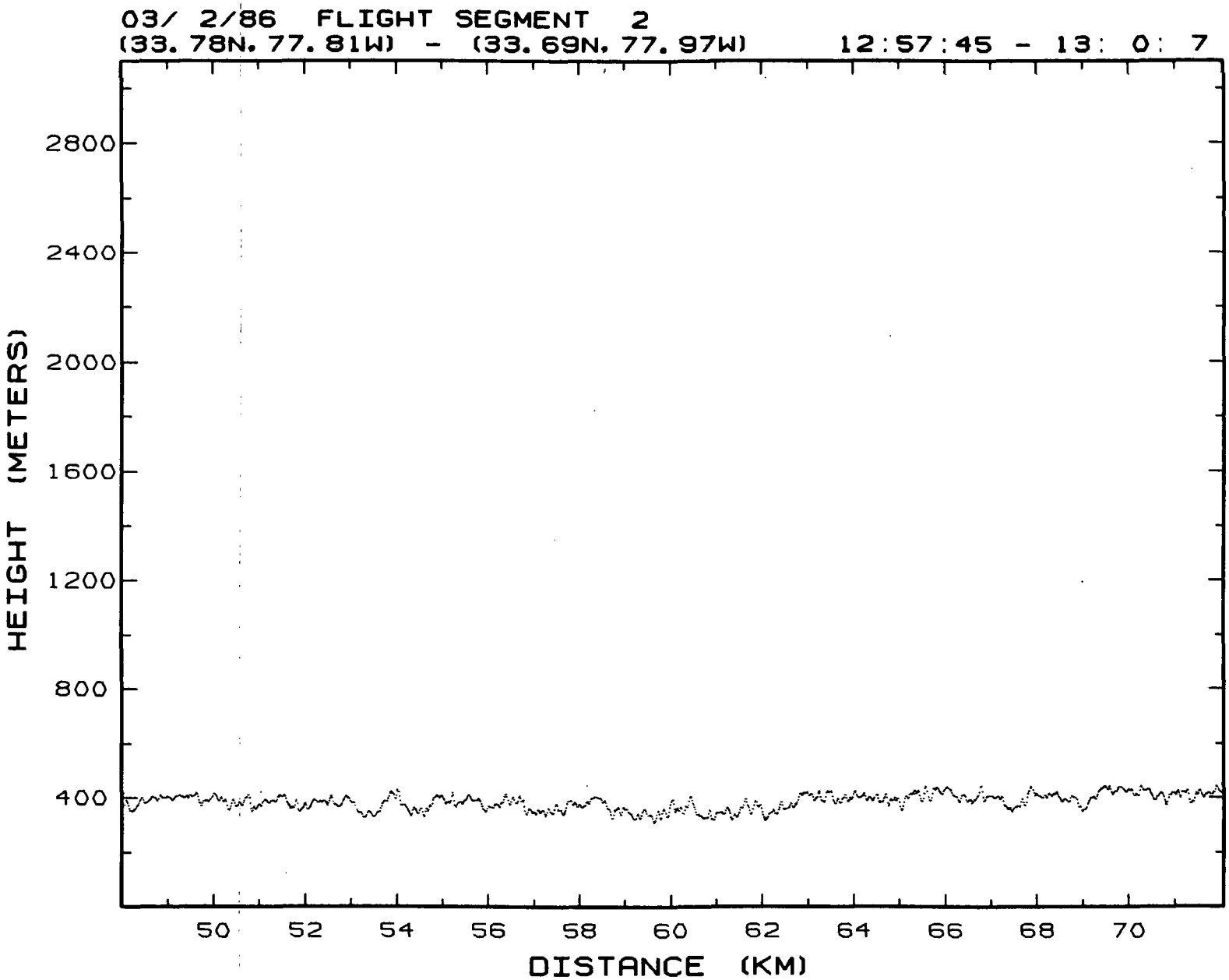

Figure 12.2c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 2, 48-72 km.

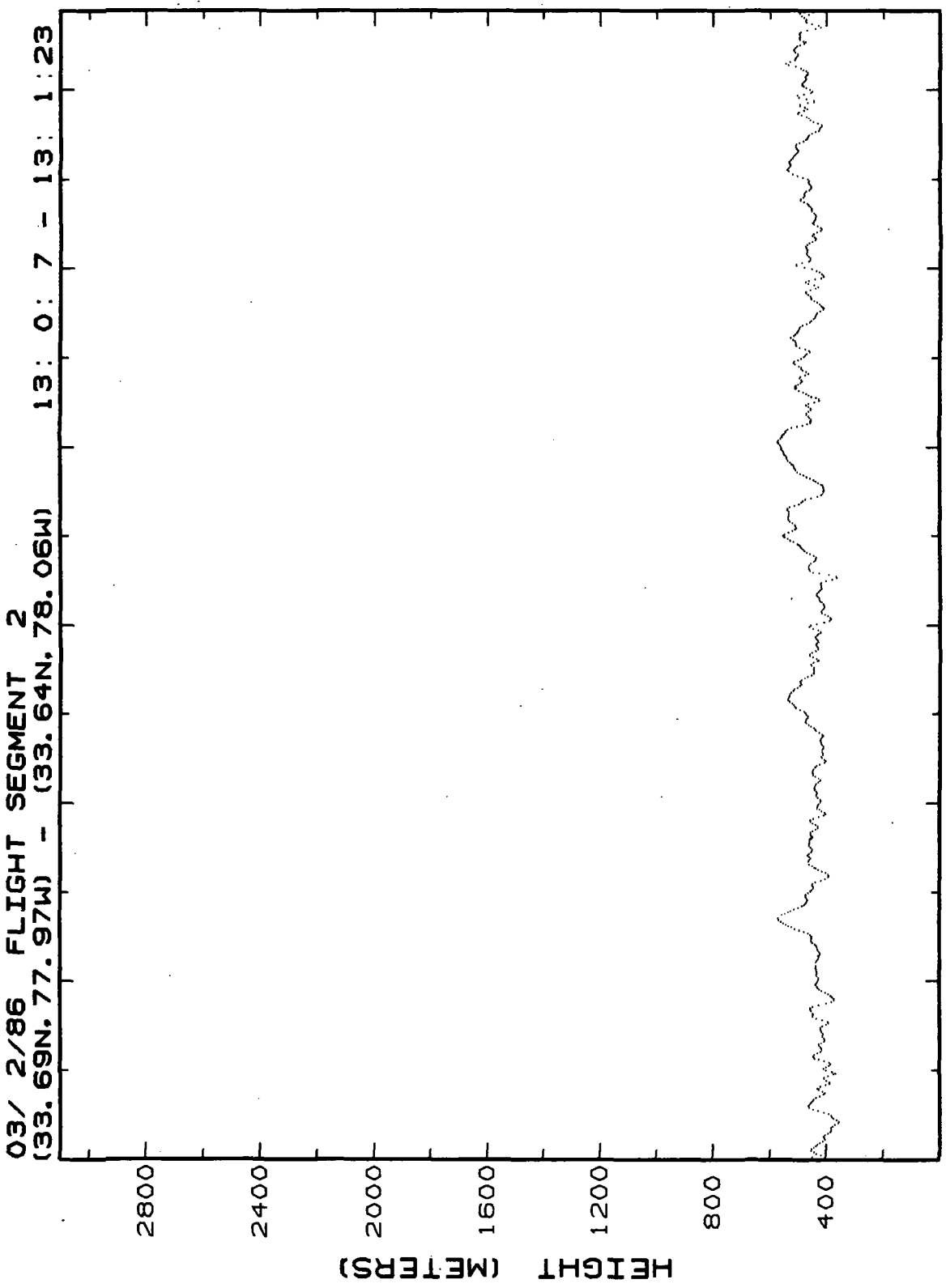

Figure 12.2d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 2, 72-85 km.

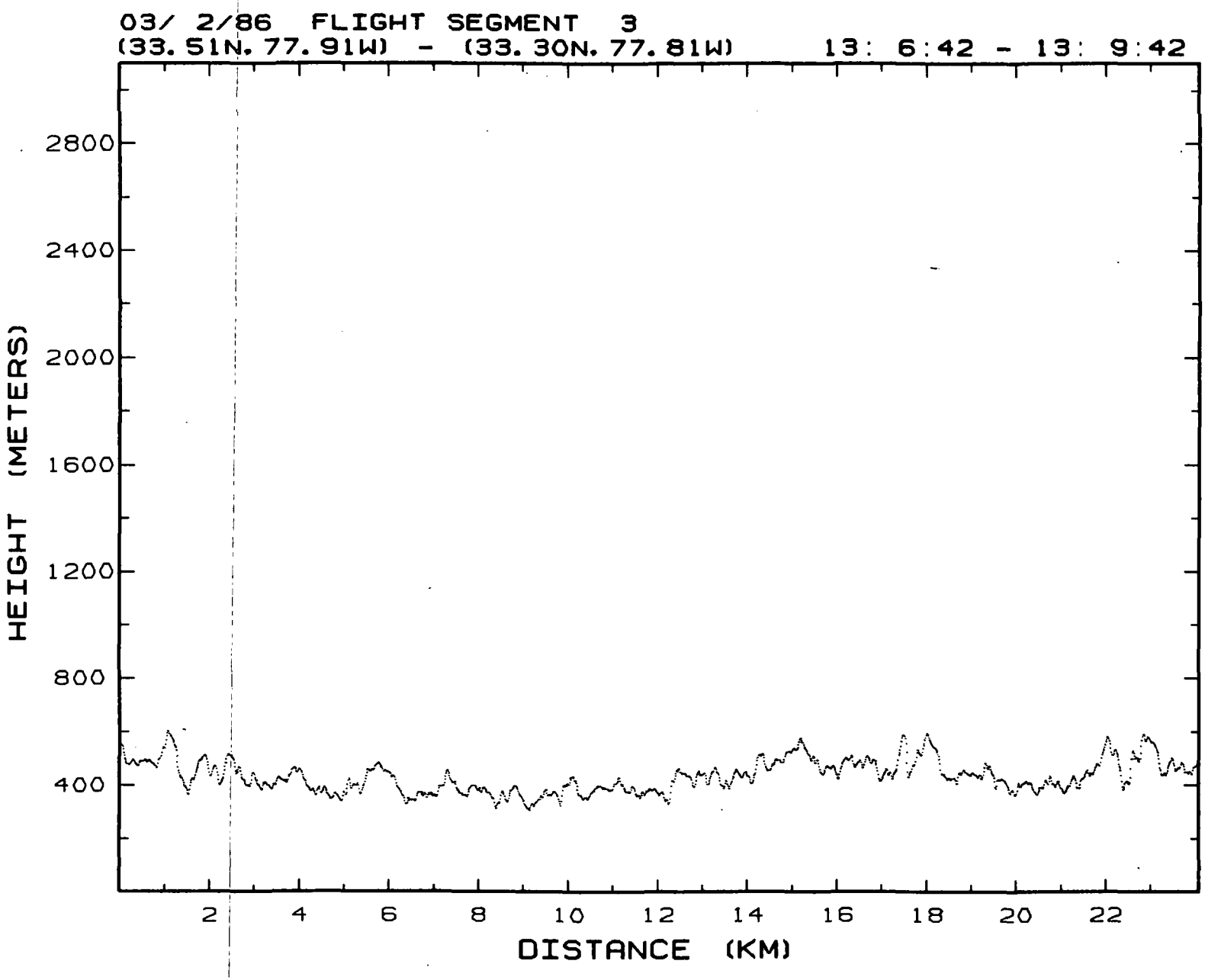

Figure 12.3a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 3, 0-24 km.

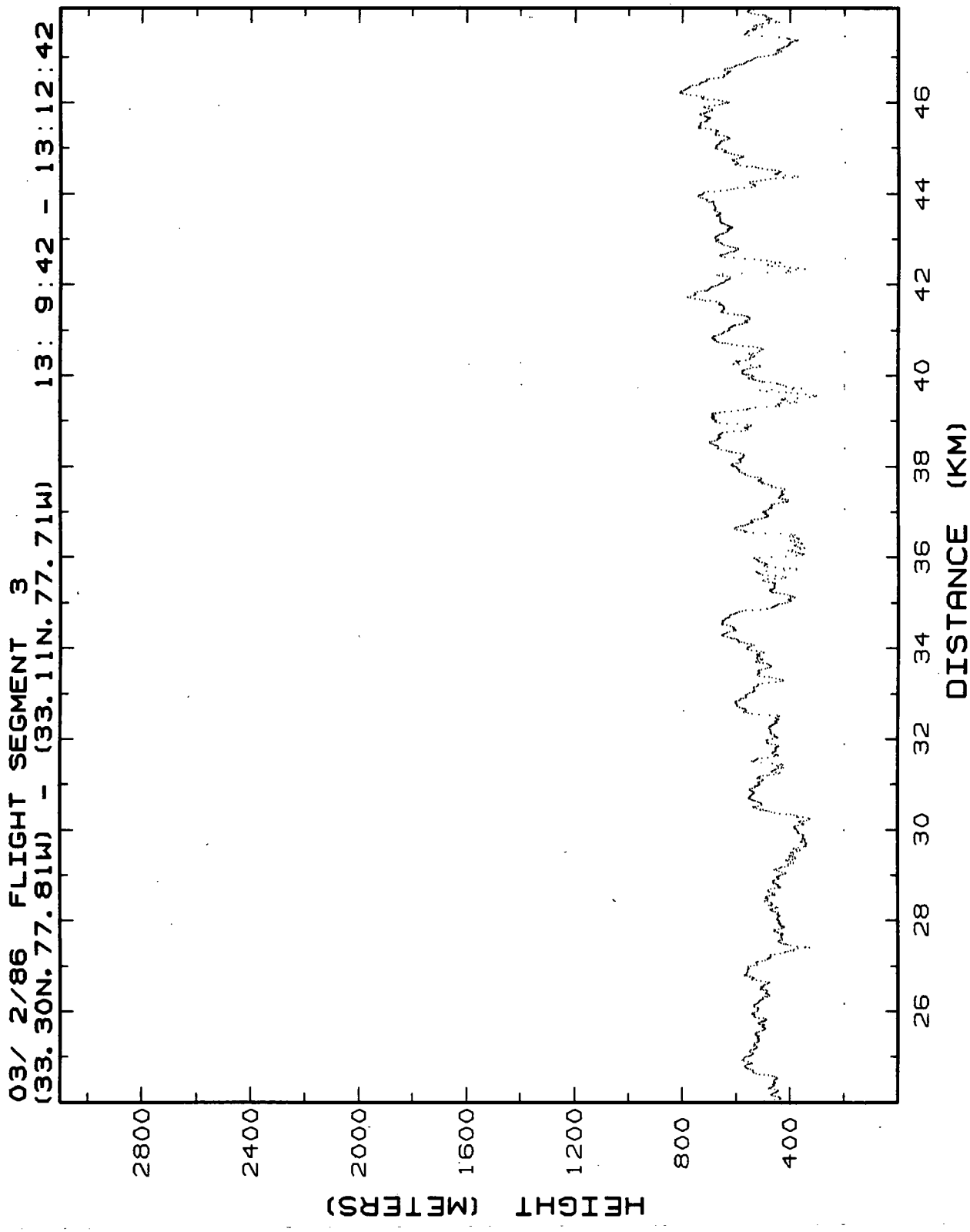

Figure 12.3b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 3, 24-48 km.

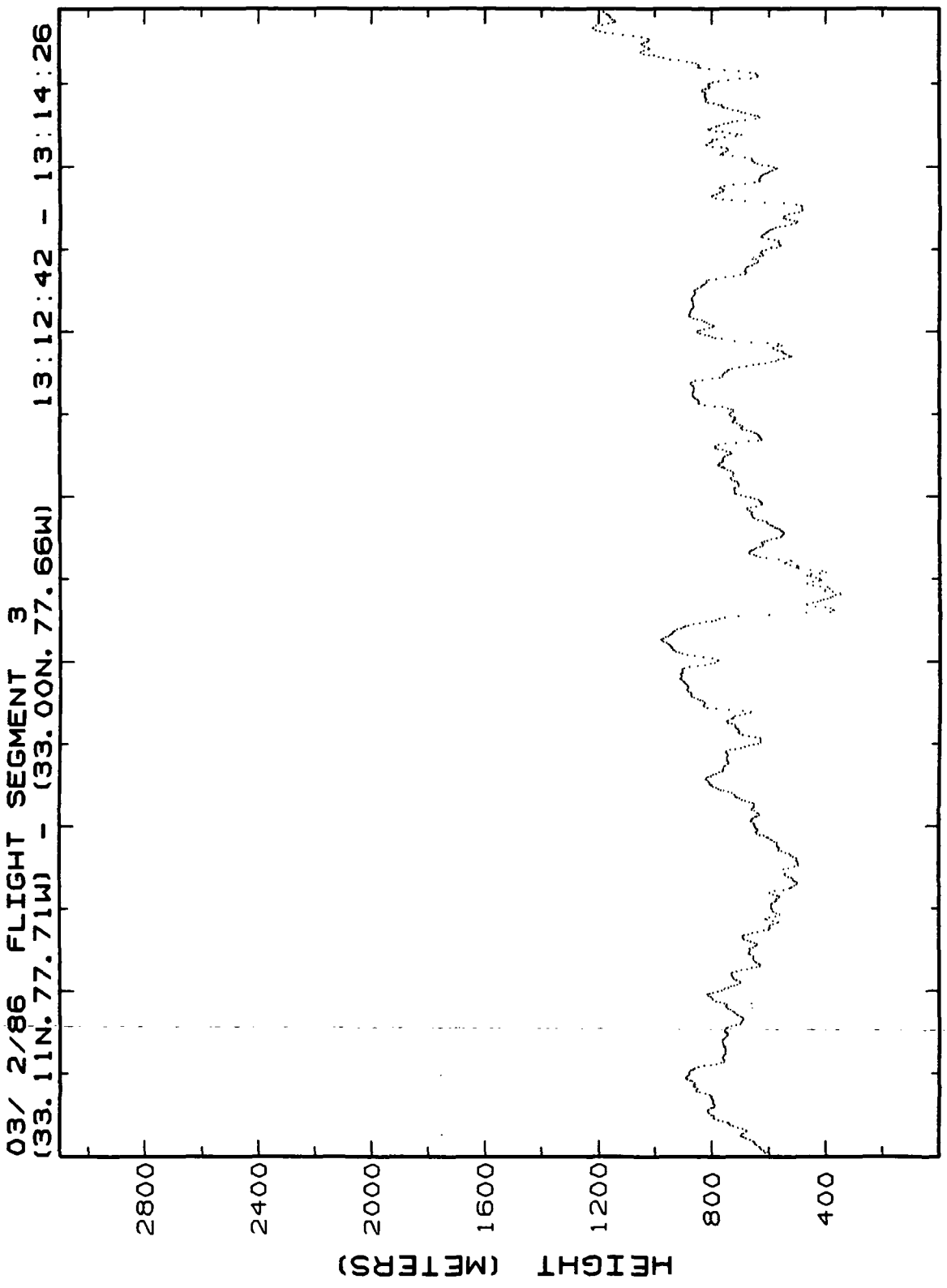

Figure 12.3c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 3, 48-62 km.

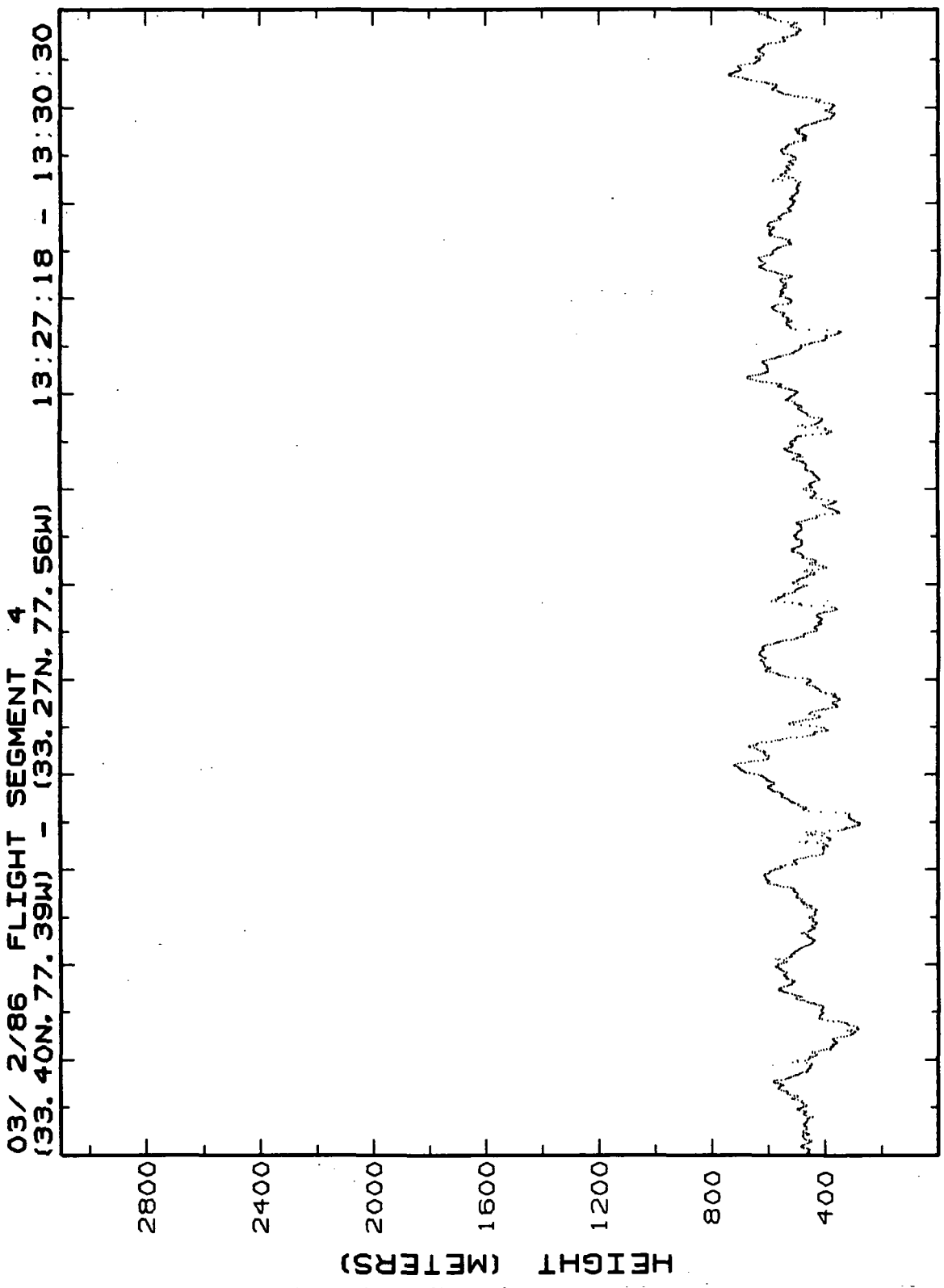

Figure 12.4a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 4, 0-24 km.

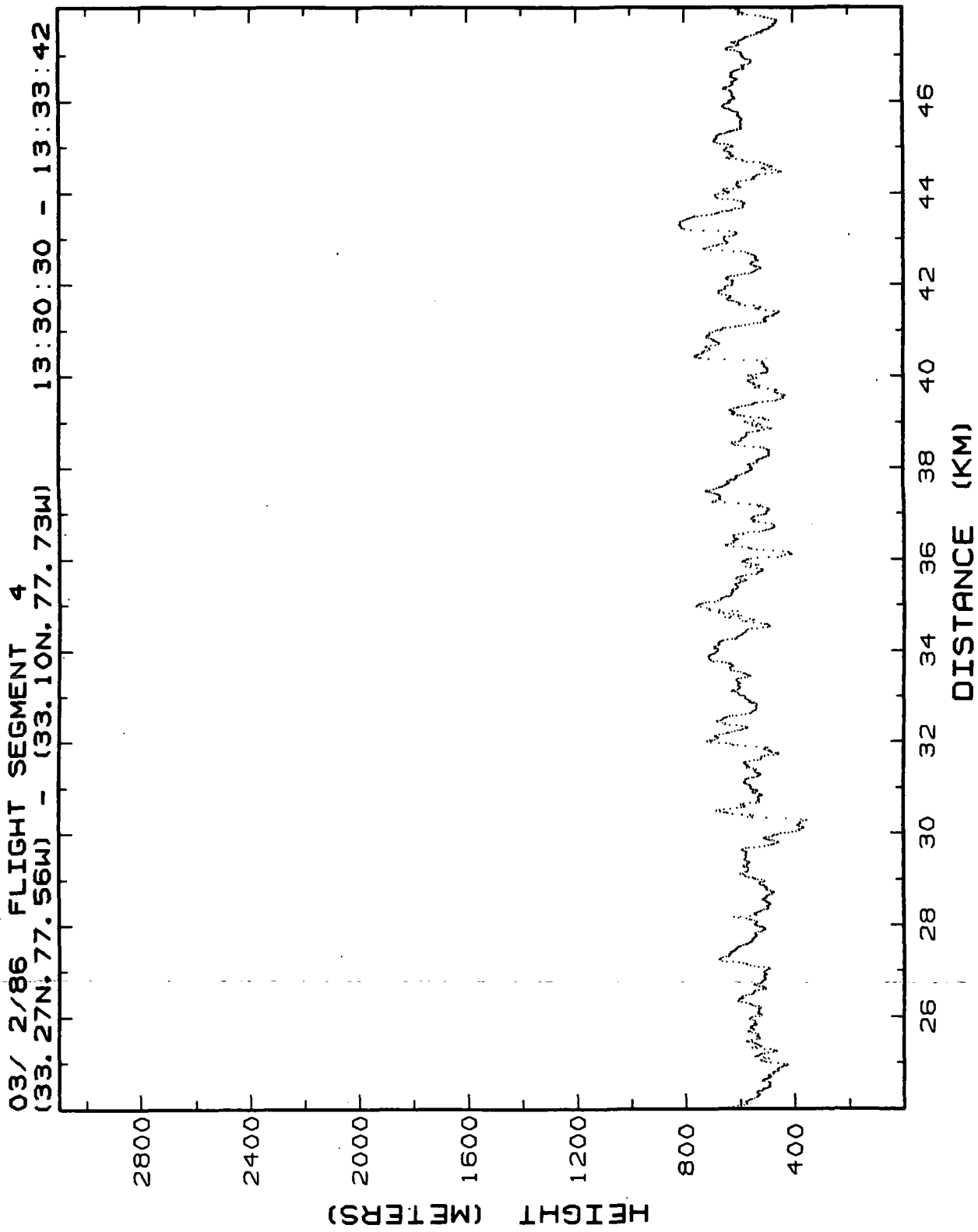

Figure 12.4b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 4, 24-48 km.

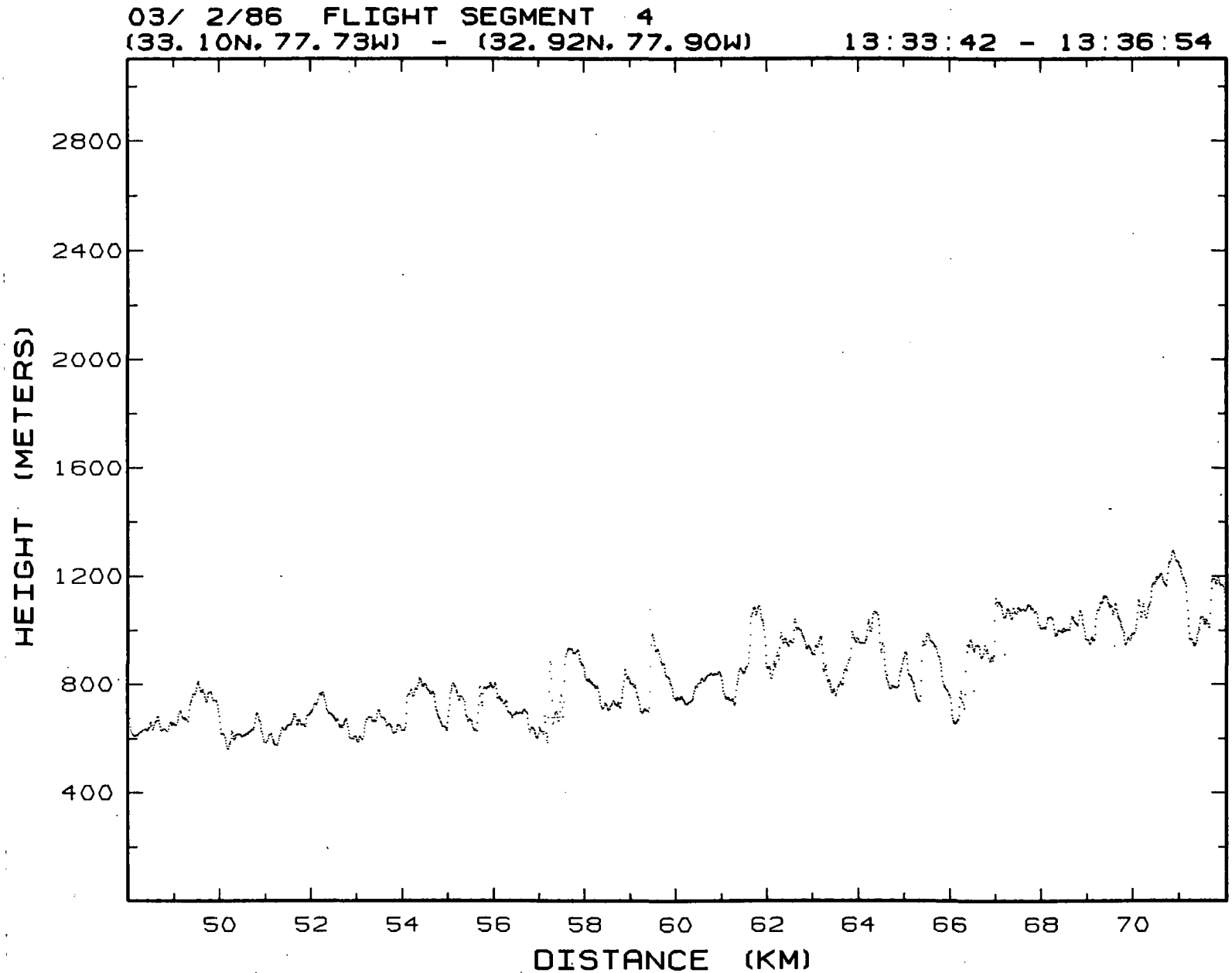

Figure 12.4c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 4, 48-72 km.

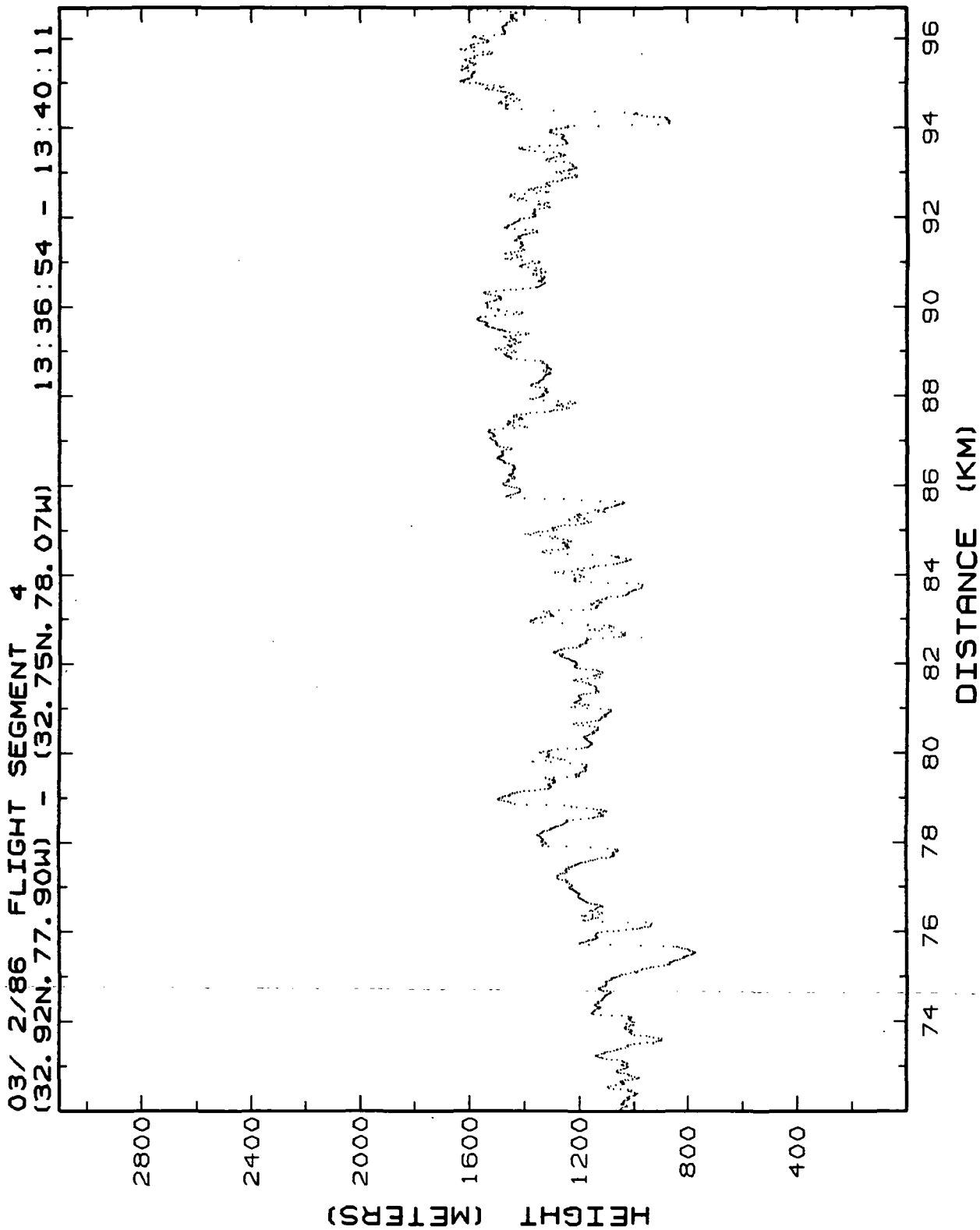

Figure 12.4d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 4, 72-97 km.

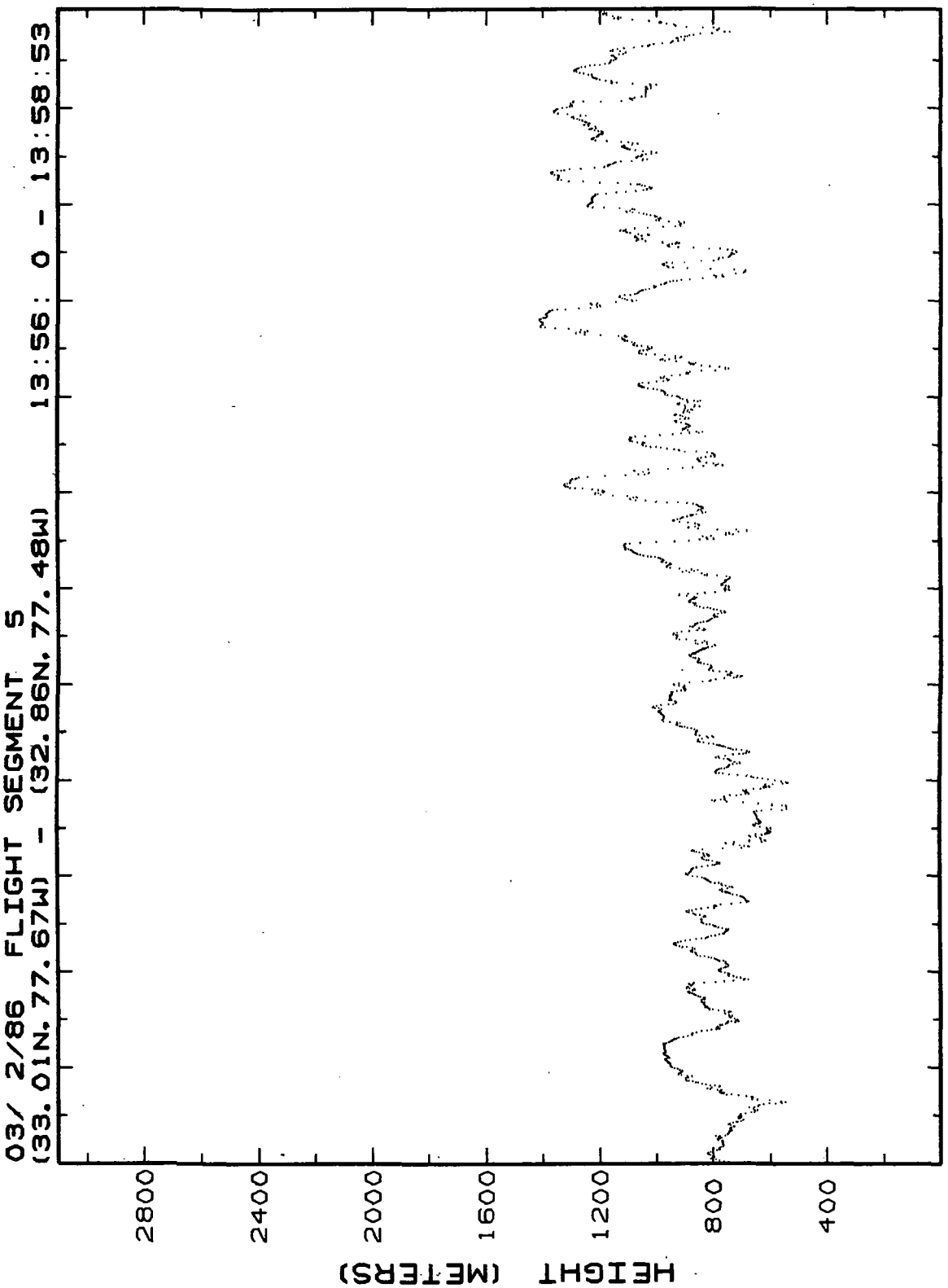

Figure 12.5a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 5, 0-24 km.

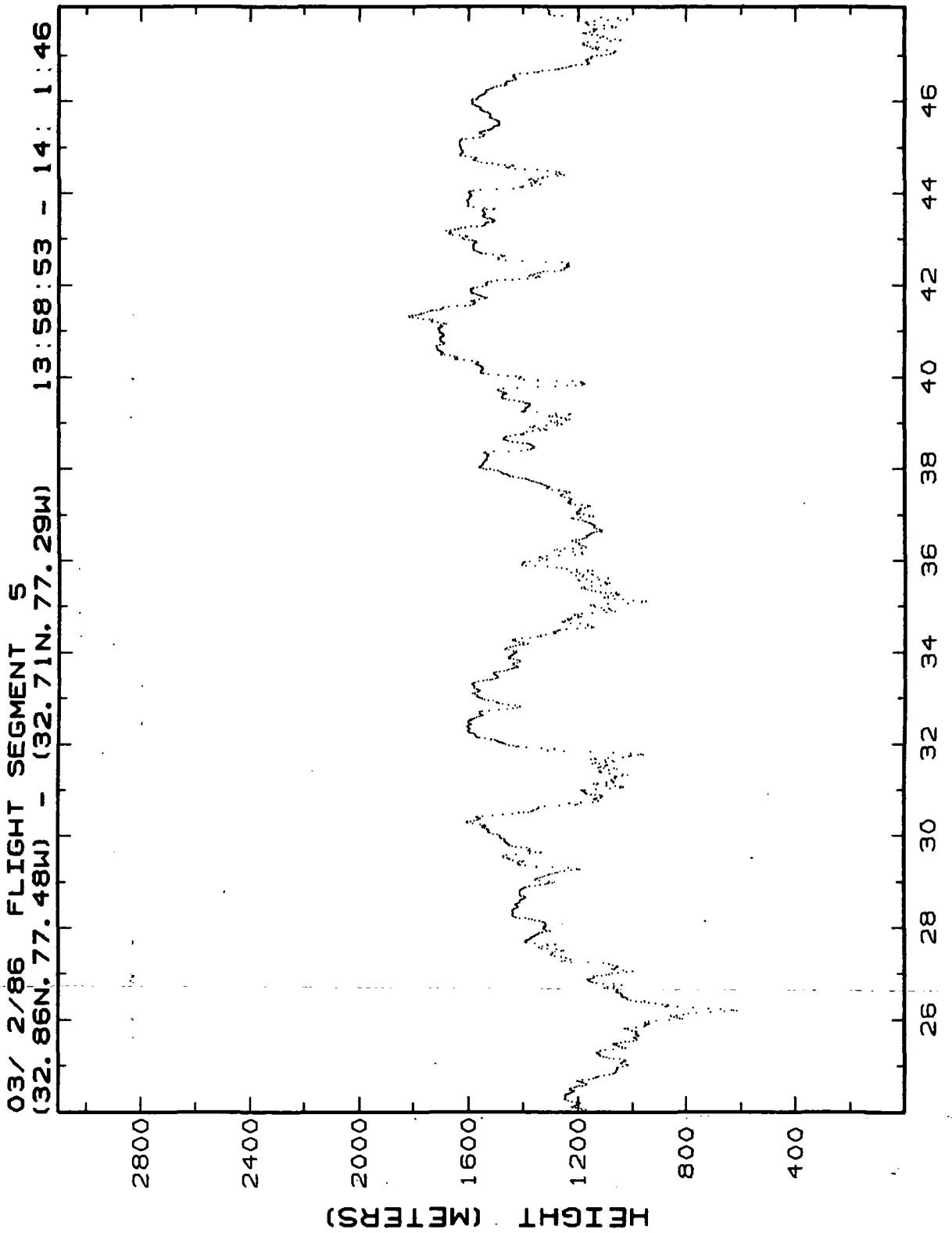

Figure 12.5b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 5, 24-48 km.

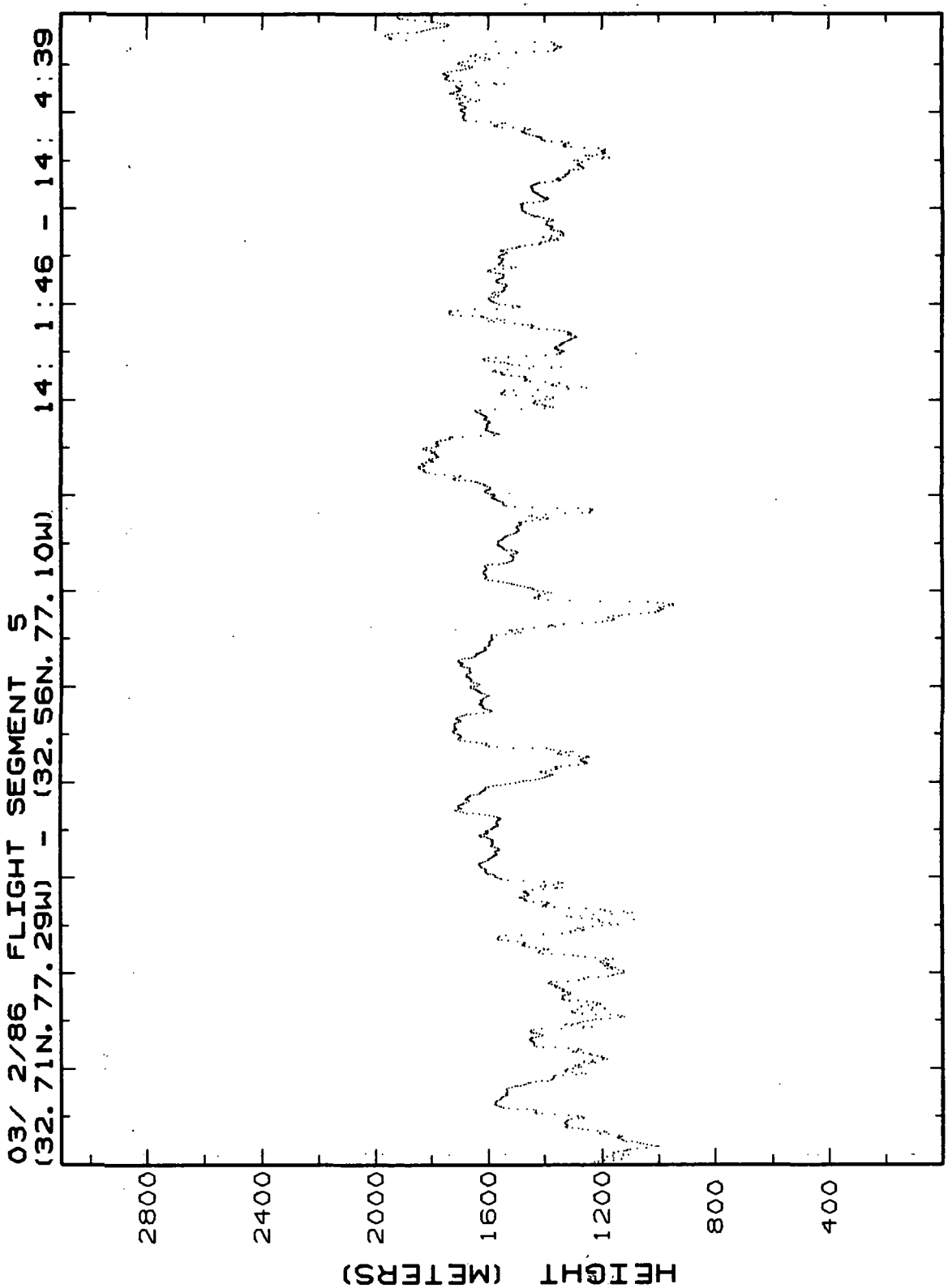

Figure 12.5c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 5, 48-72 km.

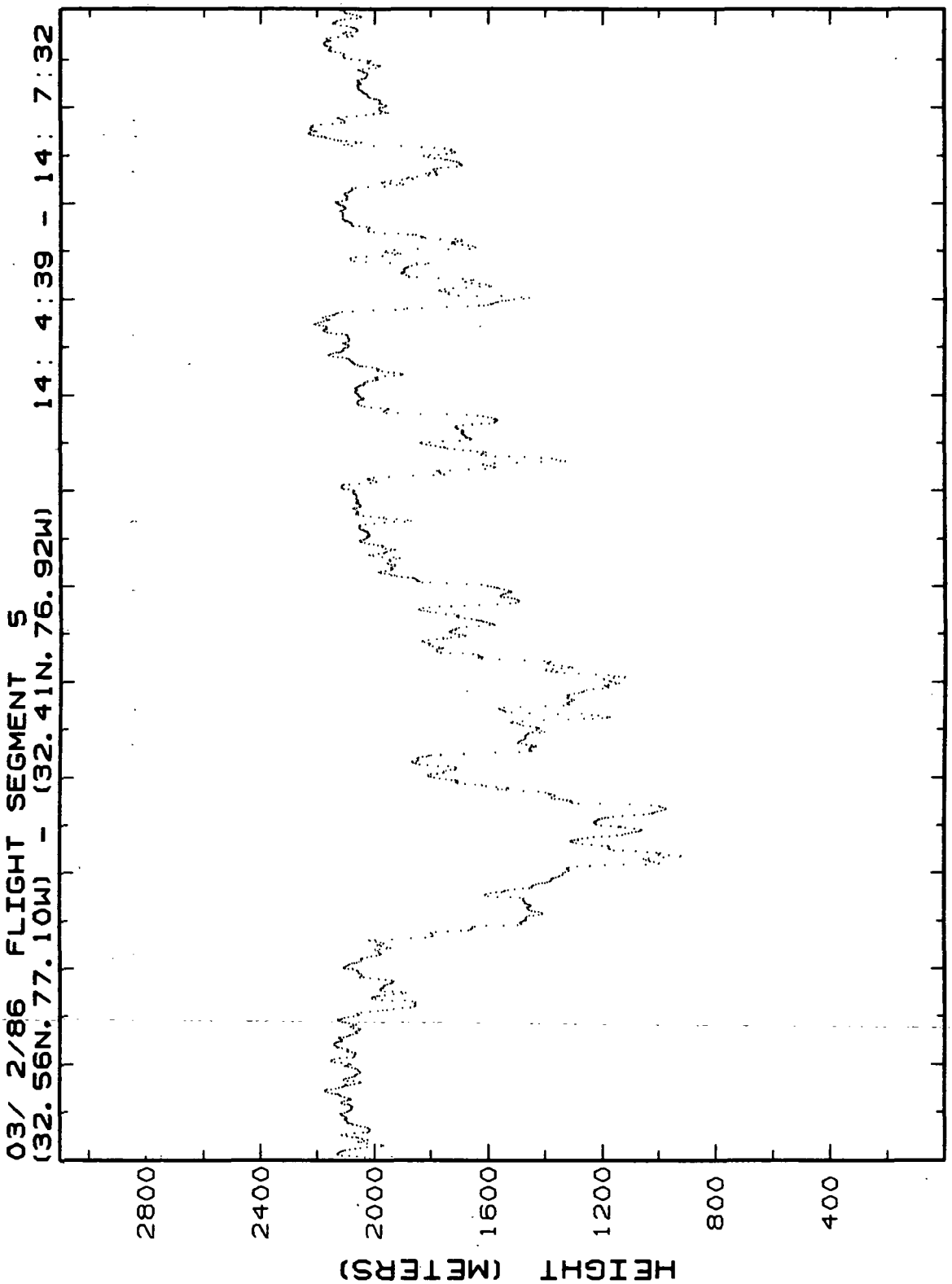

Figure 12.5d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 5, 72-96 km.

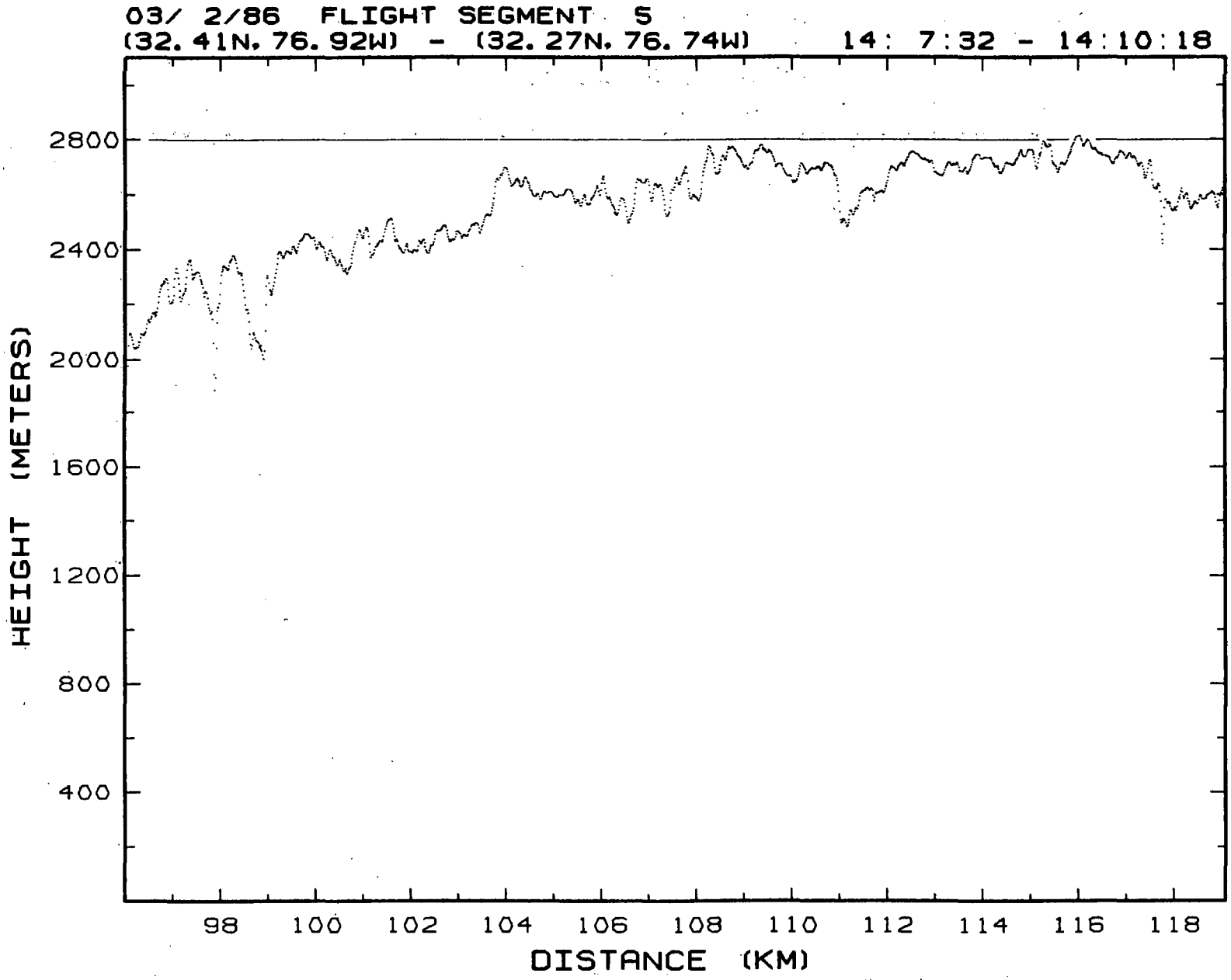

Figure 12.5e. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 5, 96-119 km.

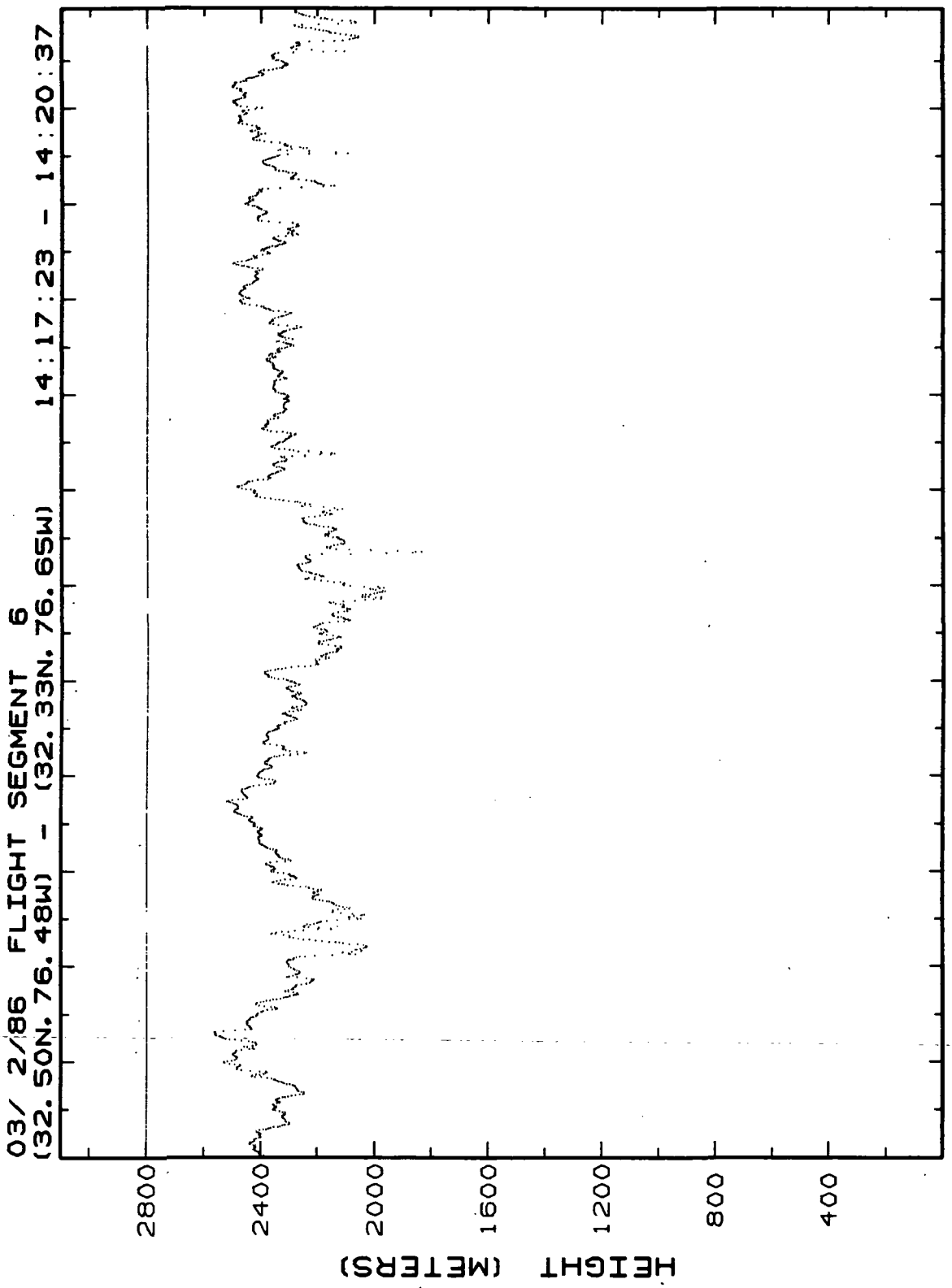

Figure 12.6a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 6, 0-24 km.

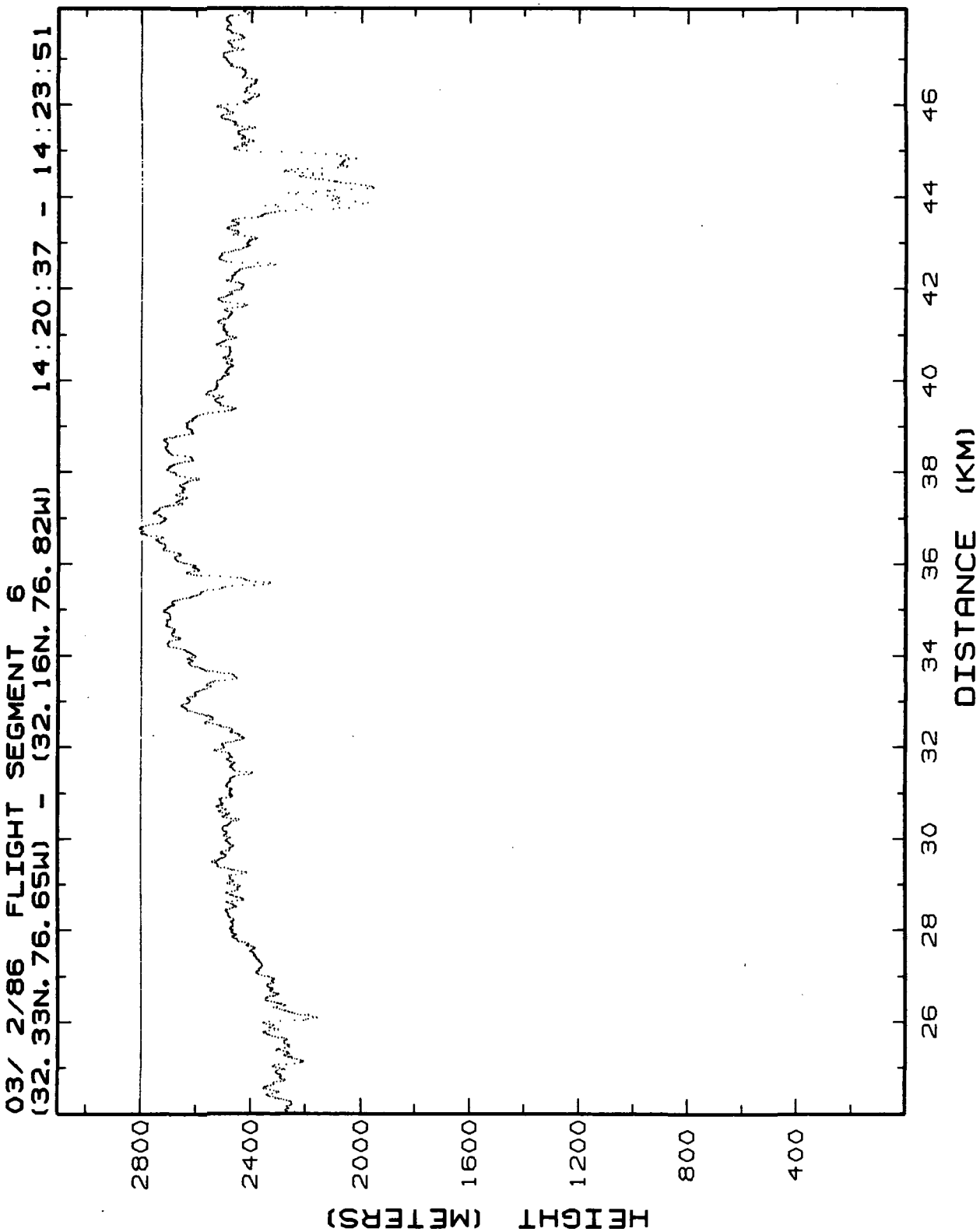

Figure 12.6b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 6, 24-41 km.

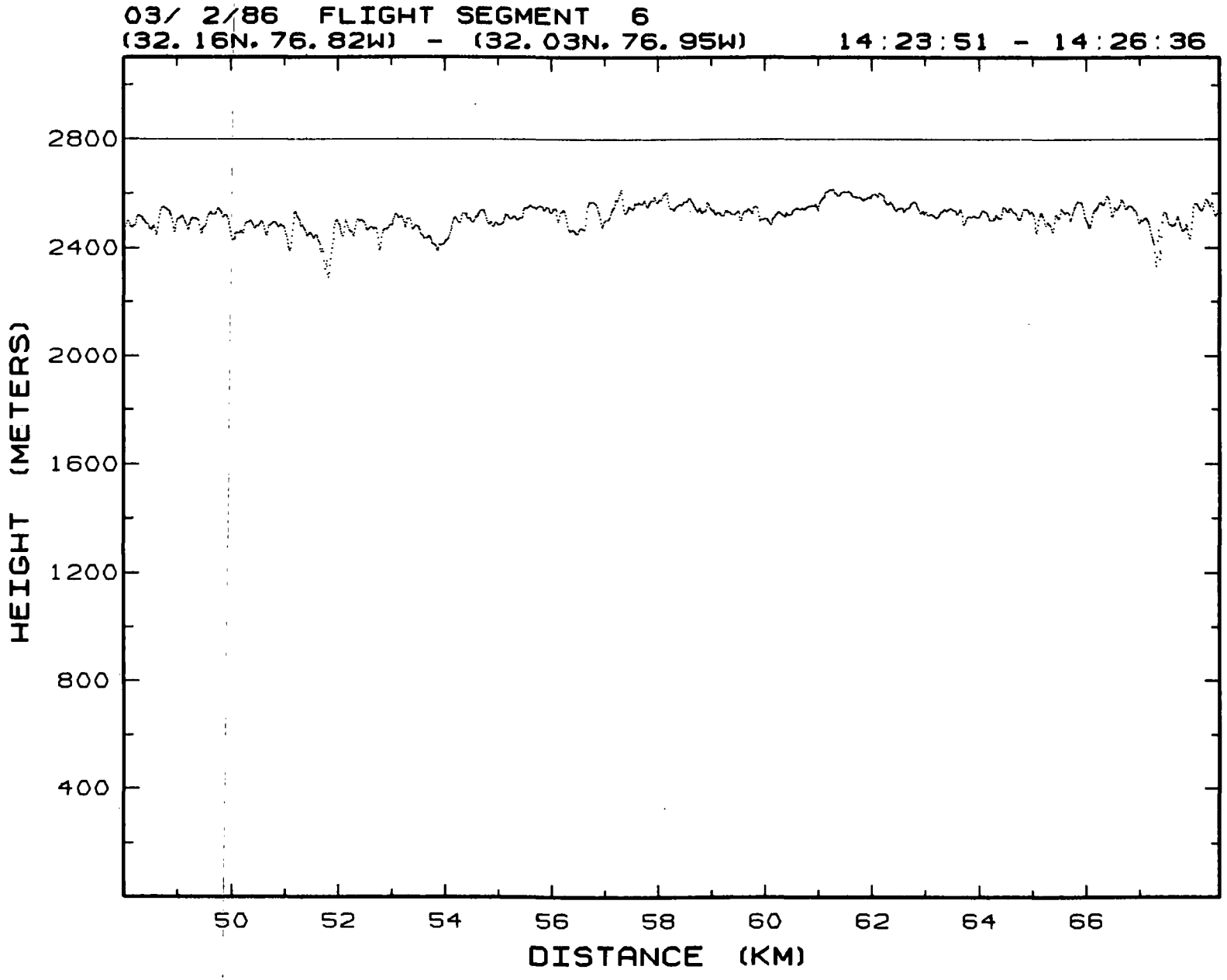

Figure 12.6c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 6, 48-69 km.

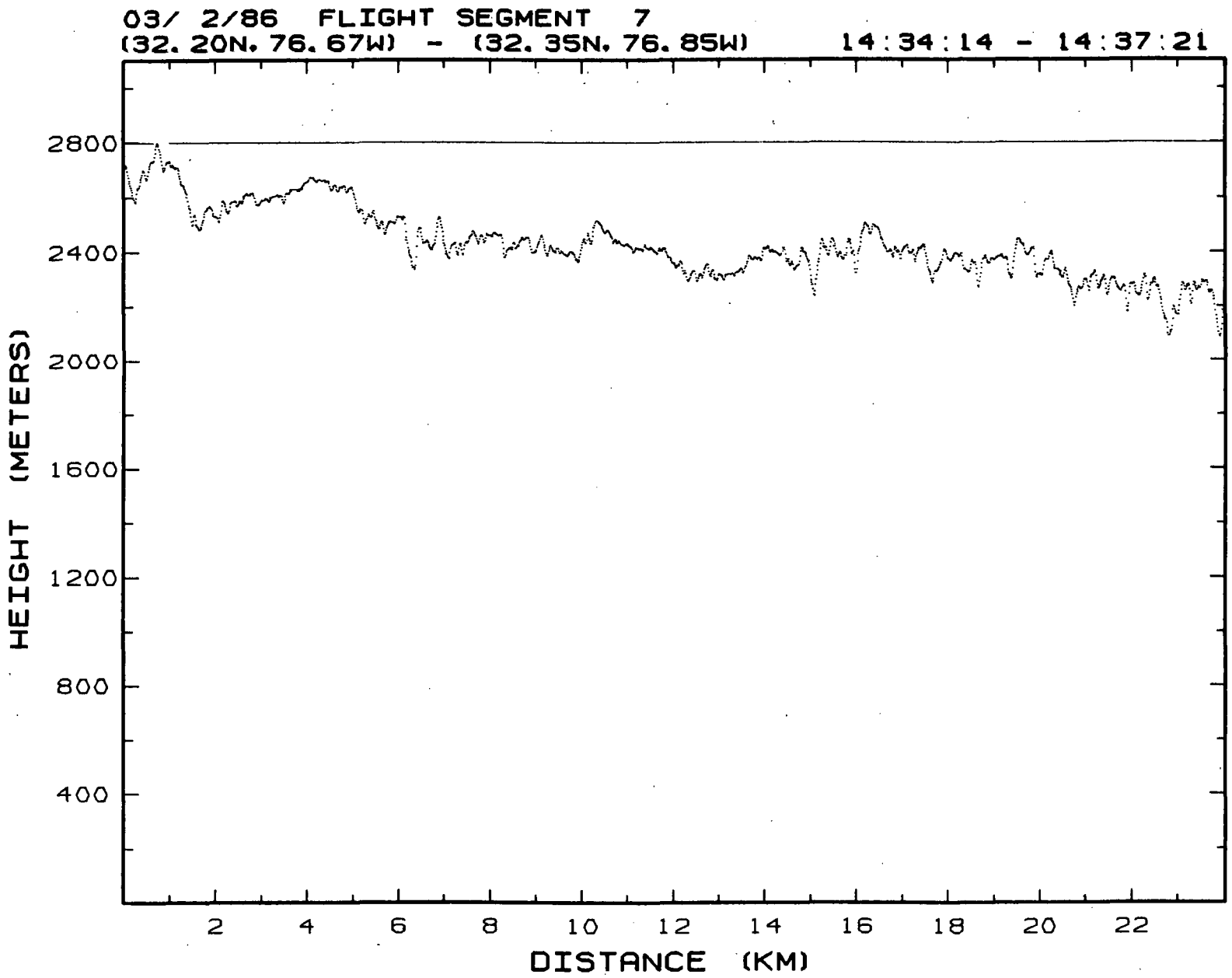

Figure 12.7a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 7, 0-24 km.

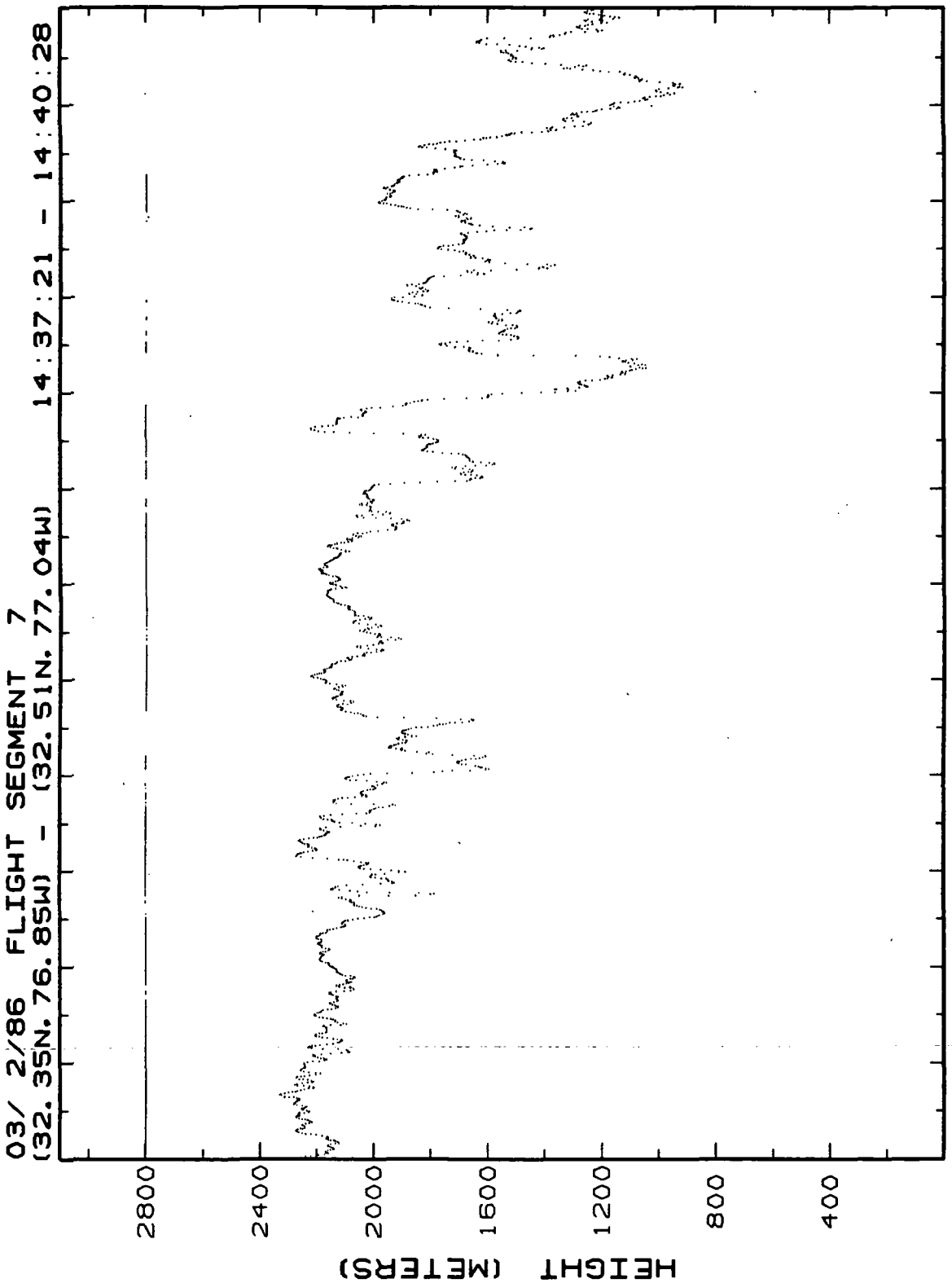

Figure 12.7b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 7, 24-43 km.

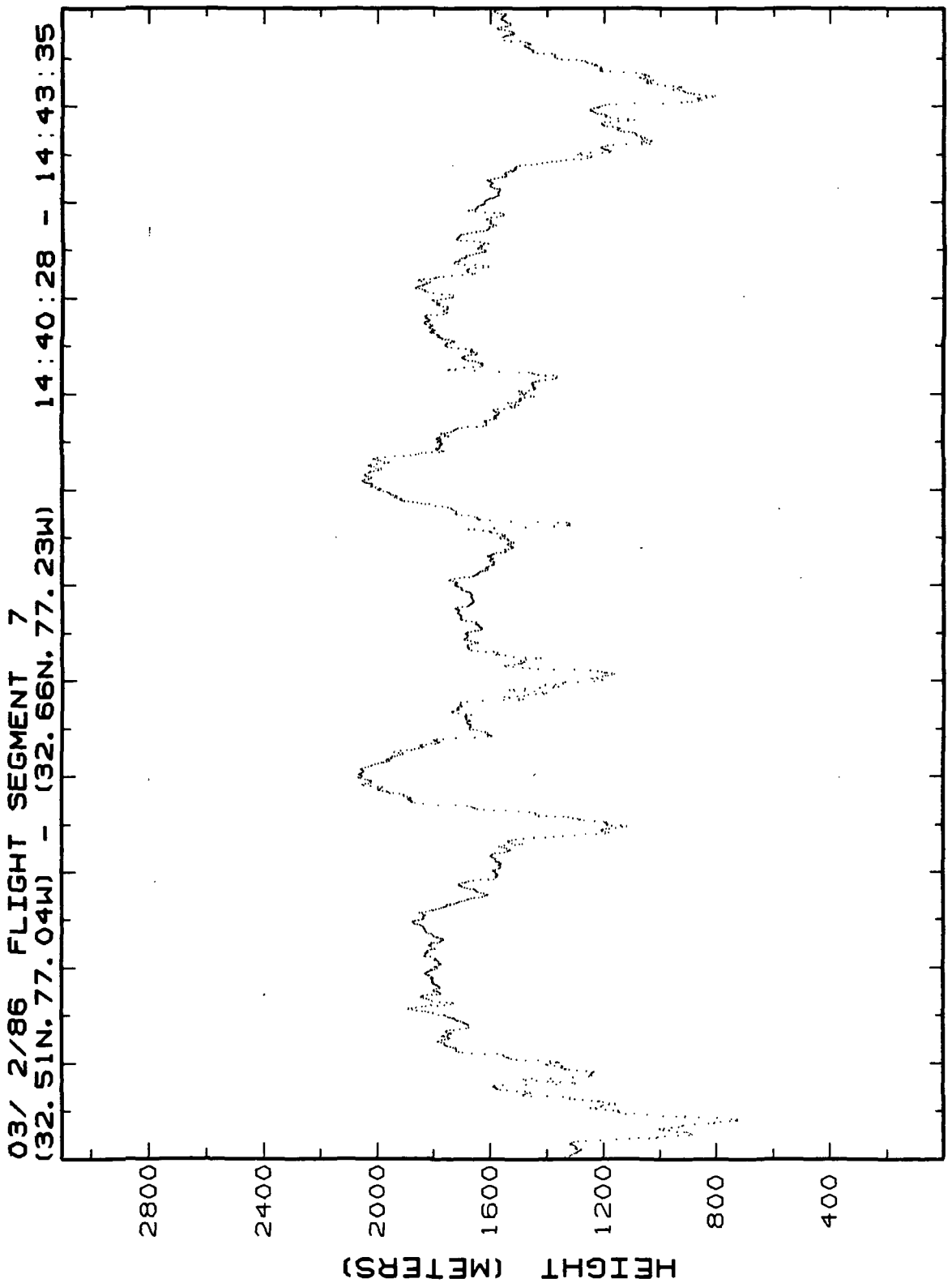

Figure 12.7c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 7, 48-72 km.

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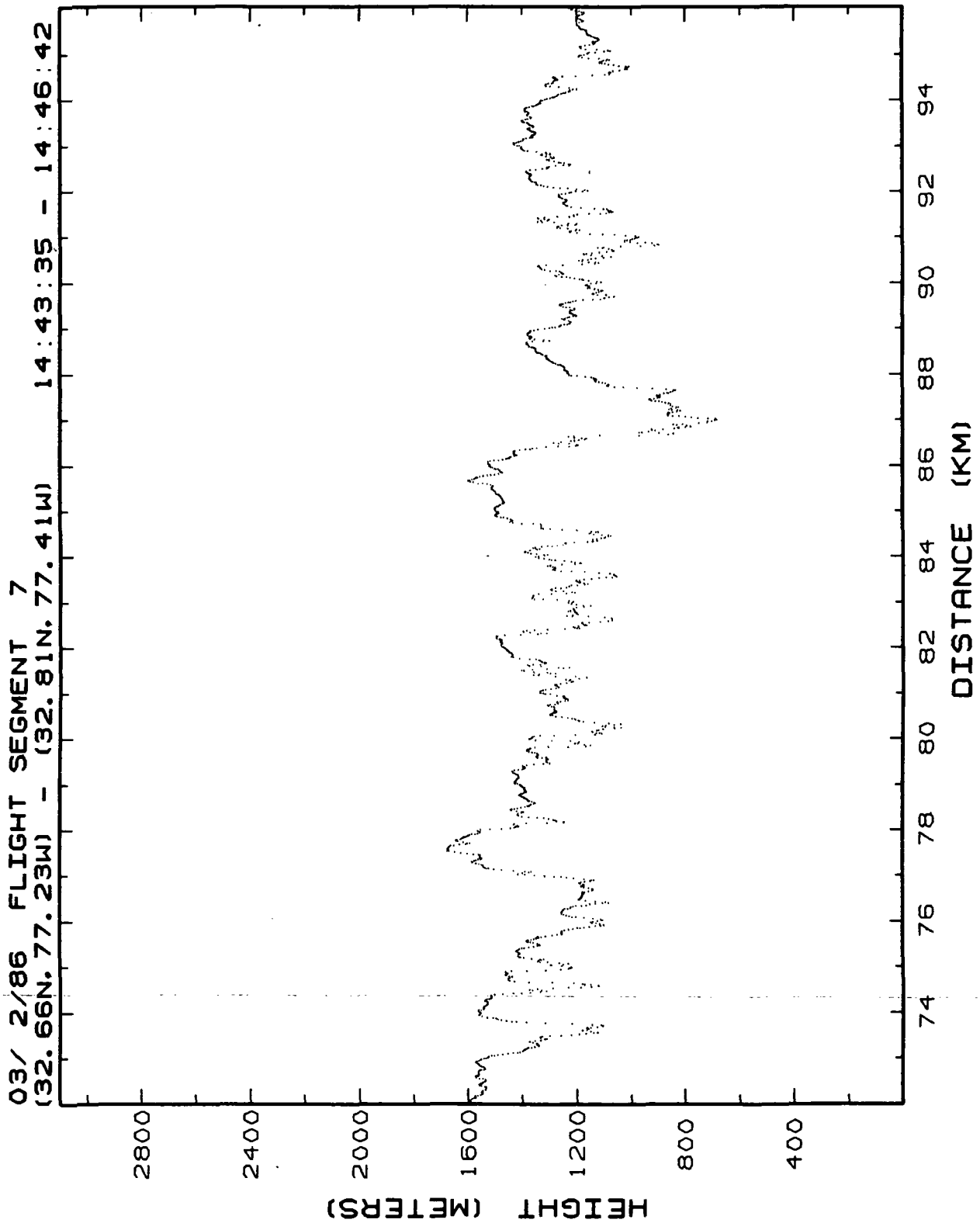

Figure 12.7d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 7, 72-96 km.

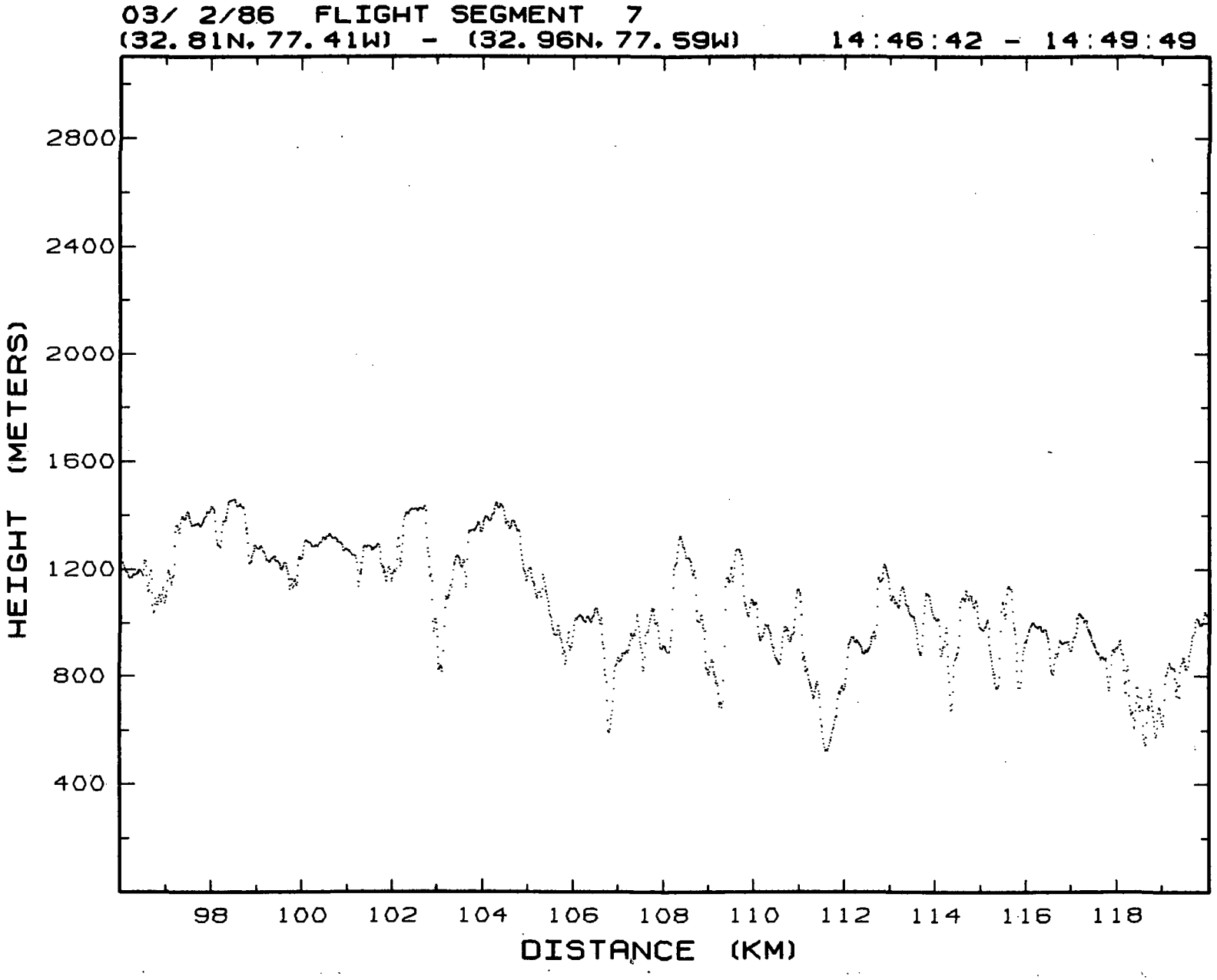

Figure 12.7e. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 7, 96-120 km.

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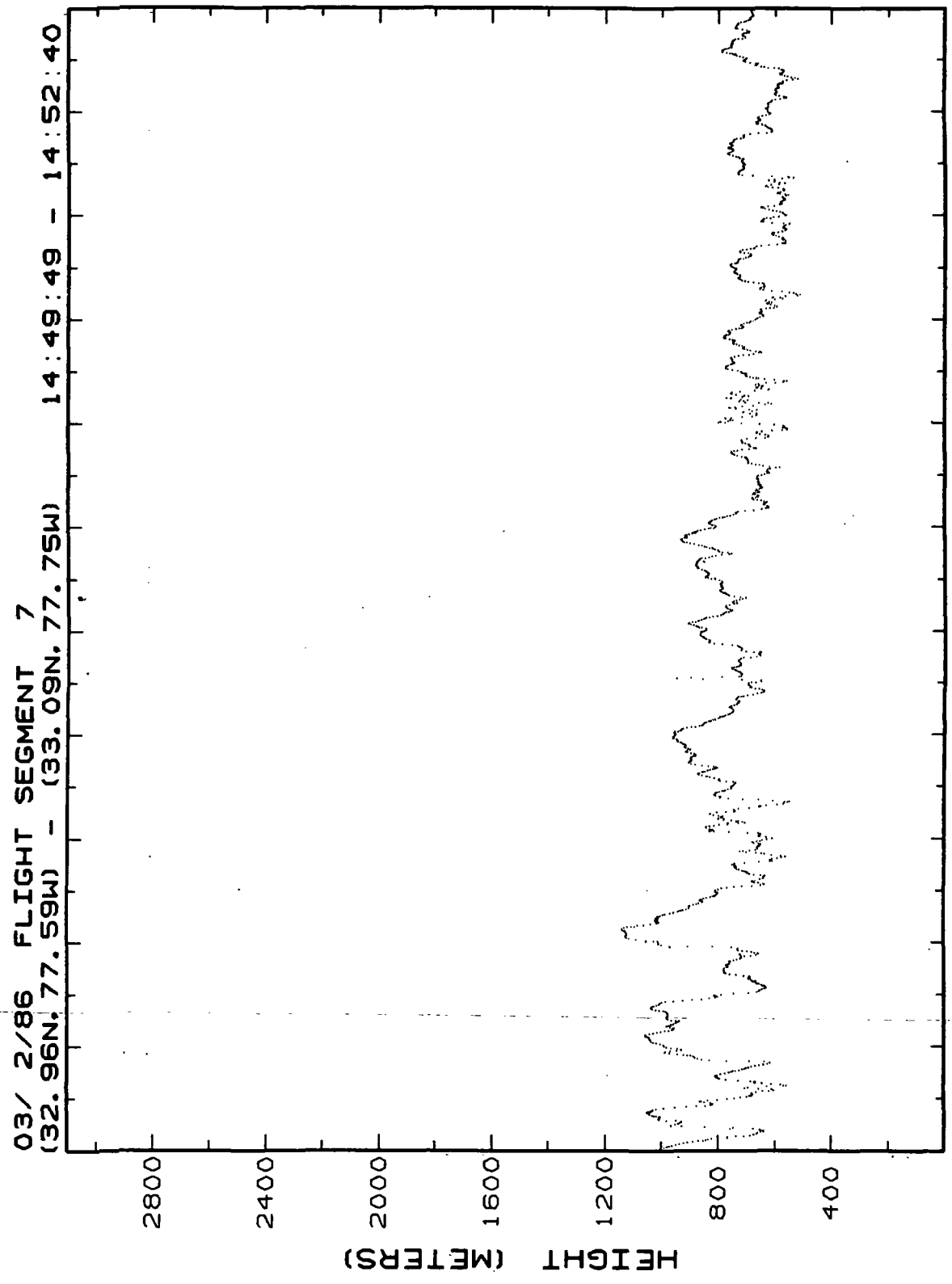

Figure 12.7f. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 7, 120-142 km.

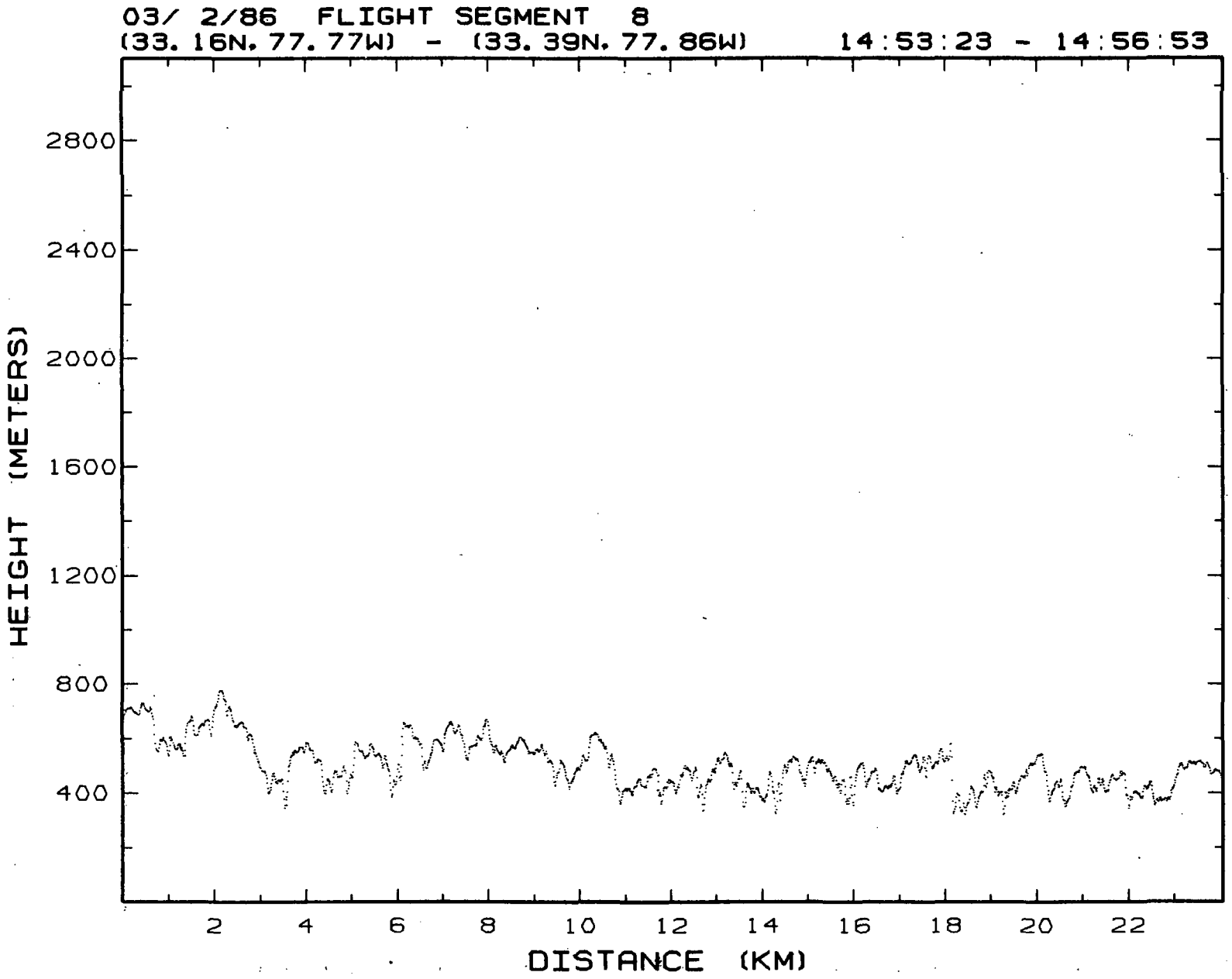

Figure 12.8a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 8, 0-24 km.

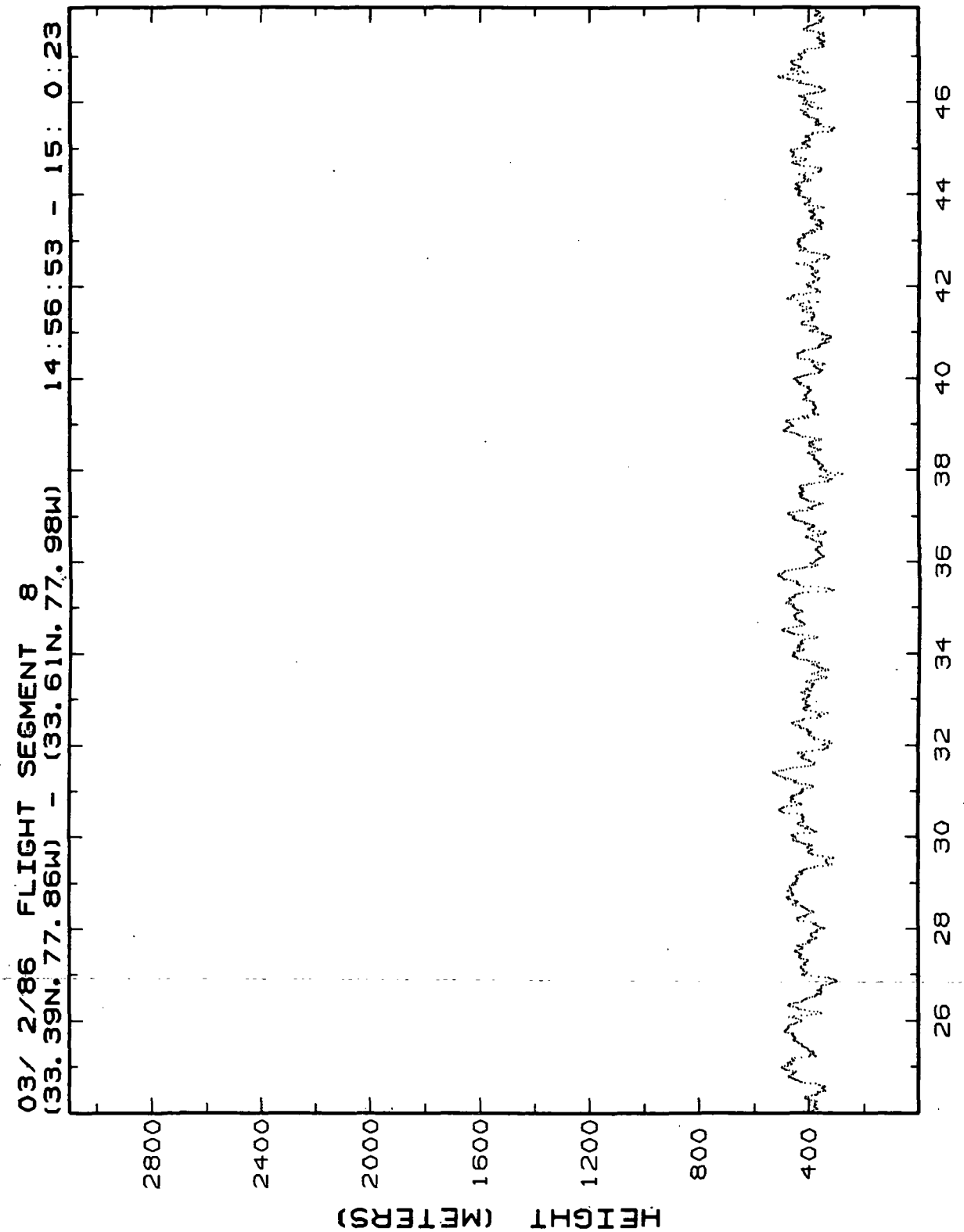

Figure 12.8b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 8, 24-48 km.

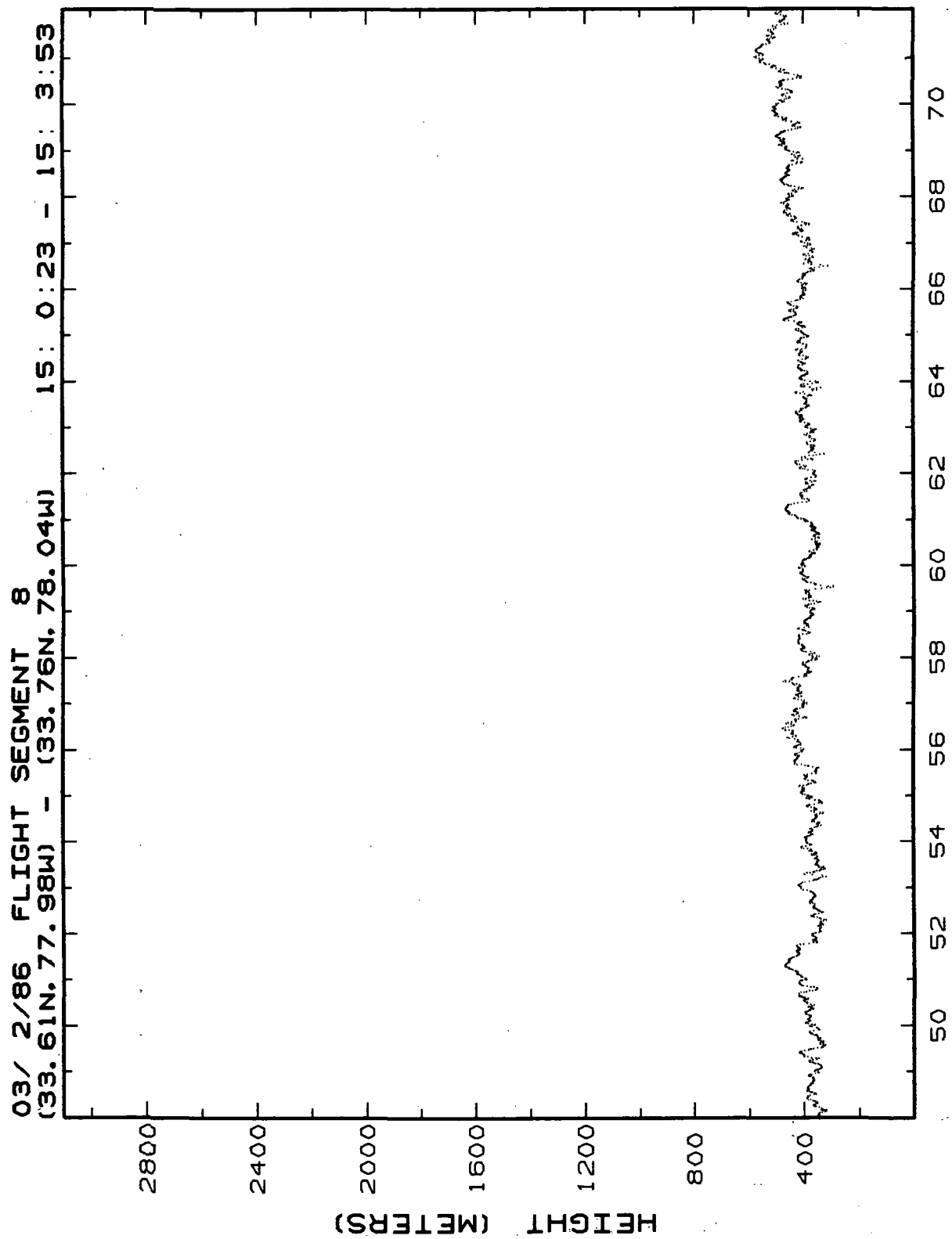

Figure 12.8c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 8, 48-72 km.

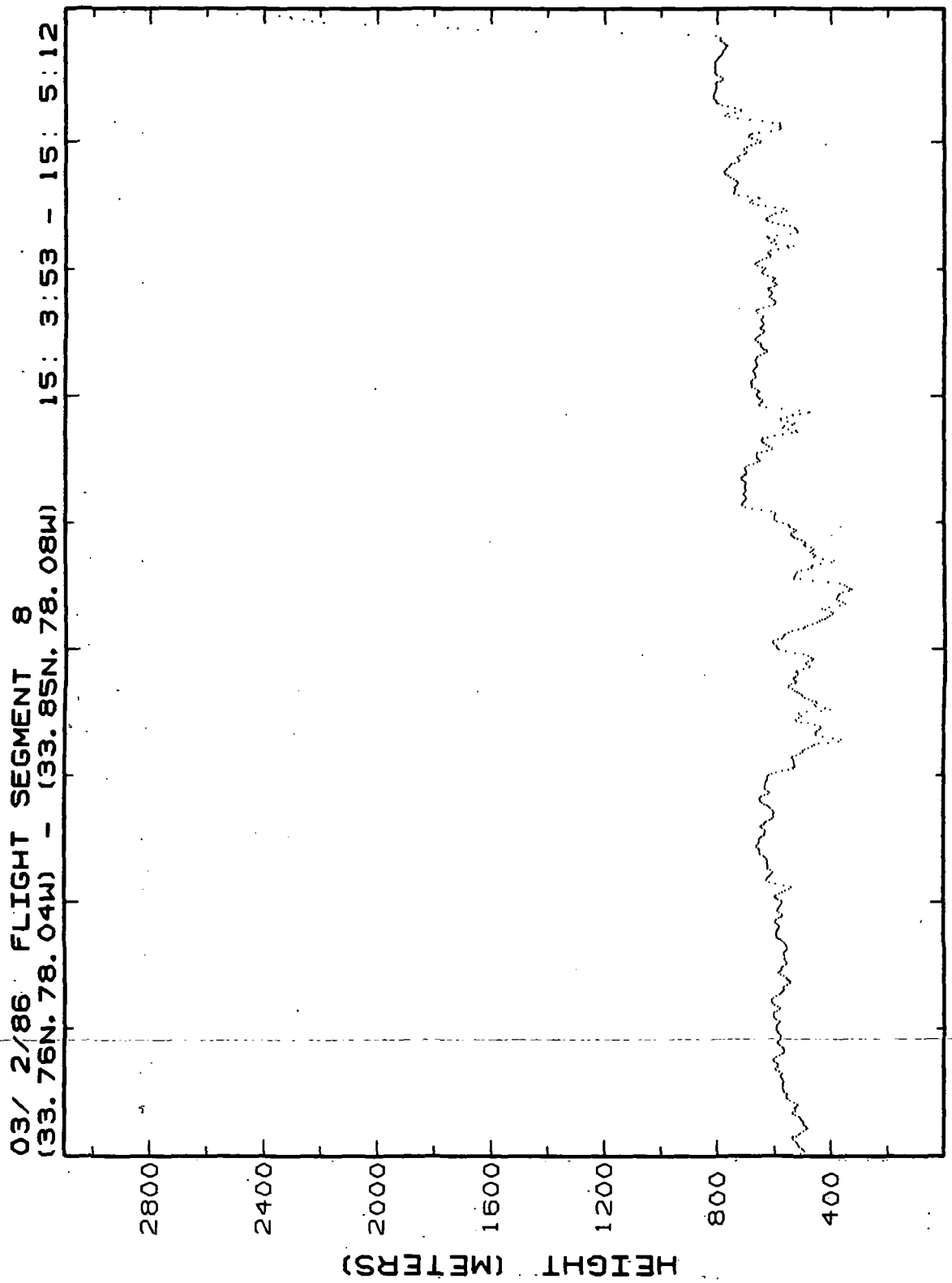

Figure 12.8d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 8, 72-81 km.

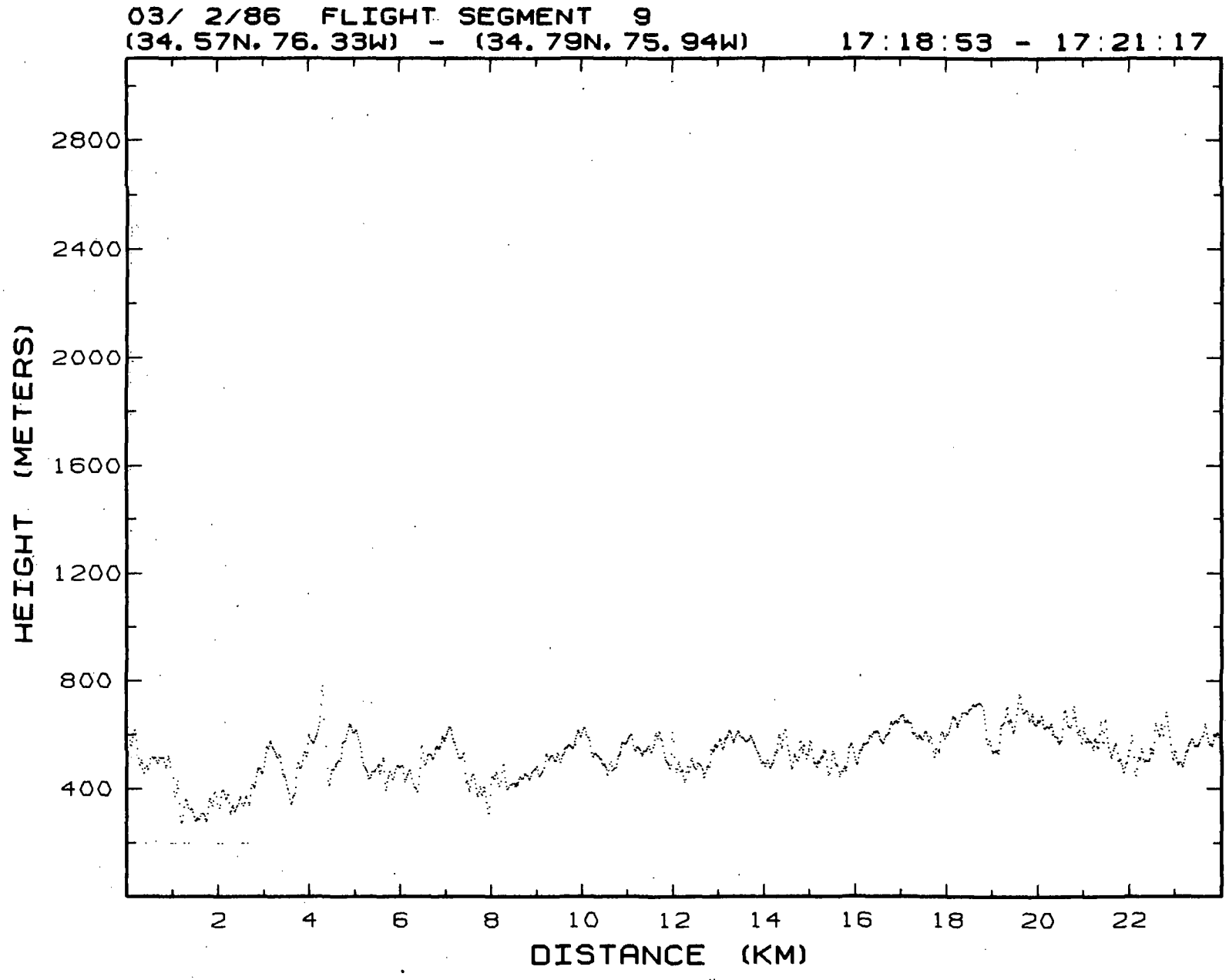

Figure 12.9a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 9, 0-24 km.

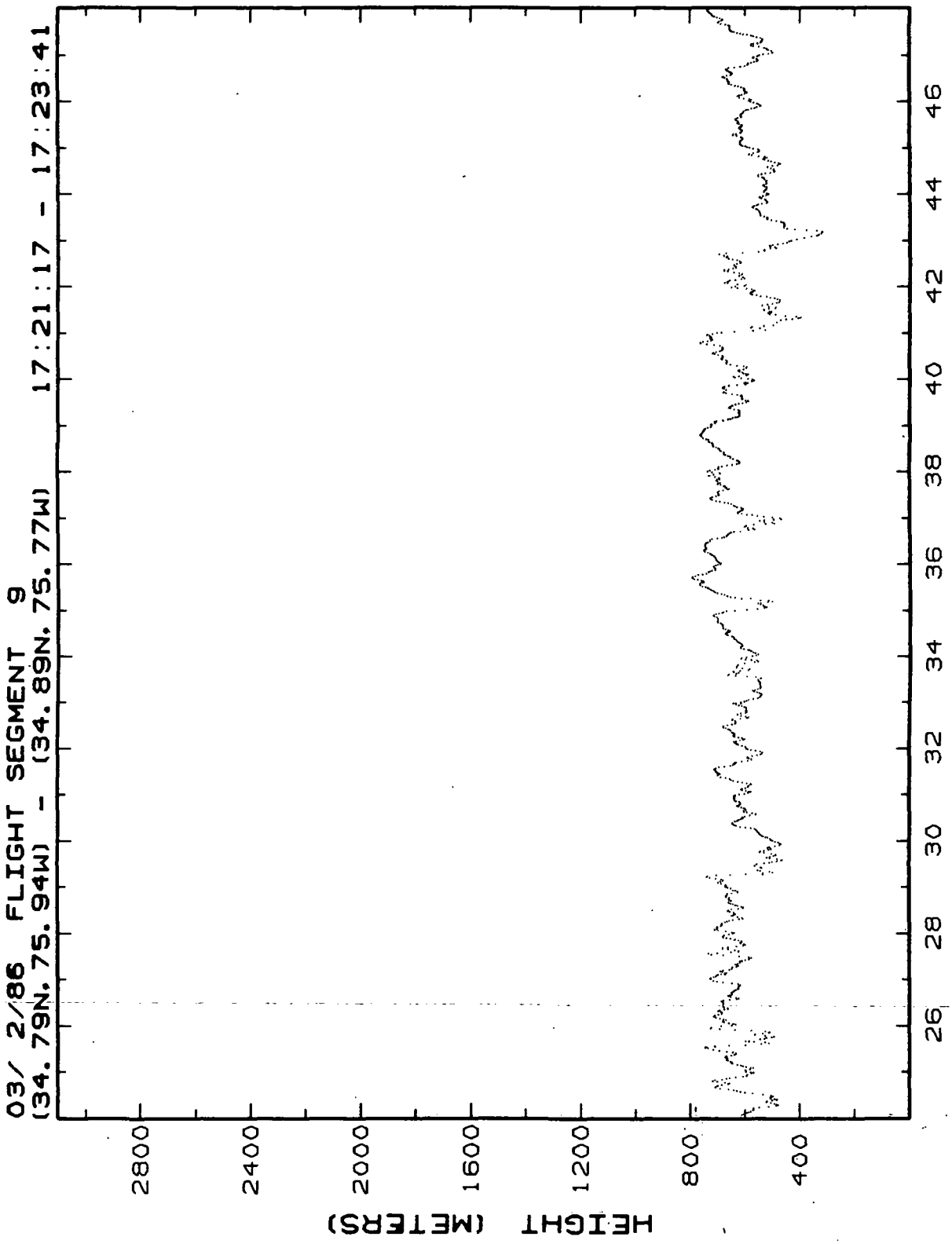

Figure 12.9b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 9, 24-48 km.

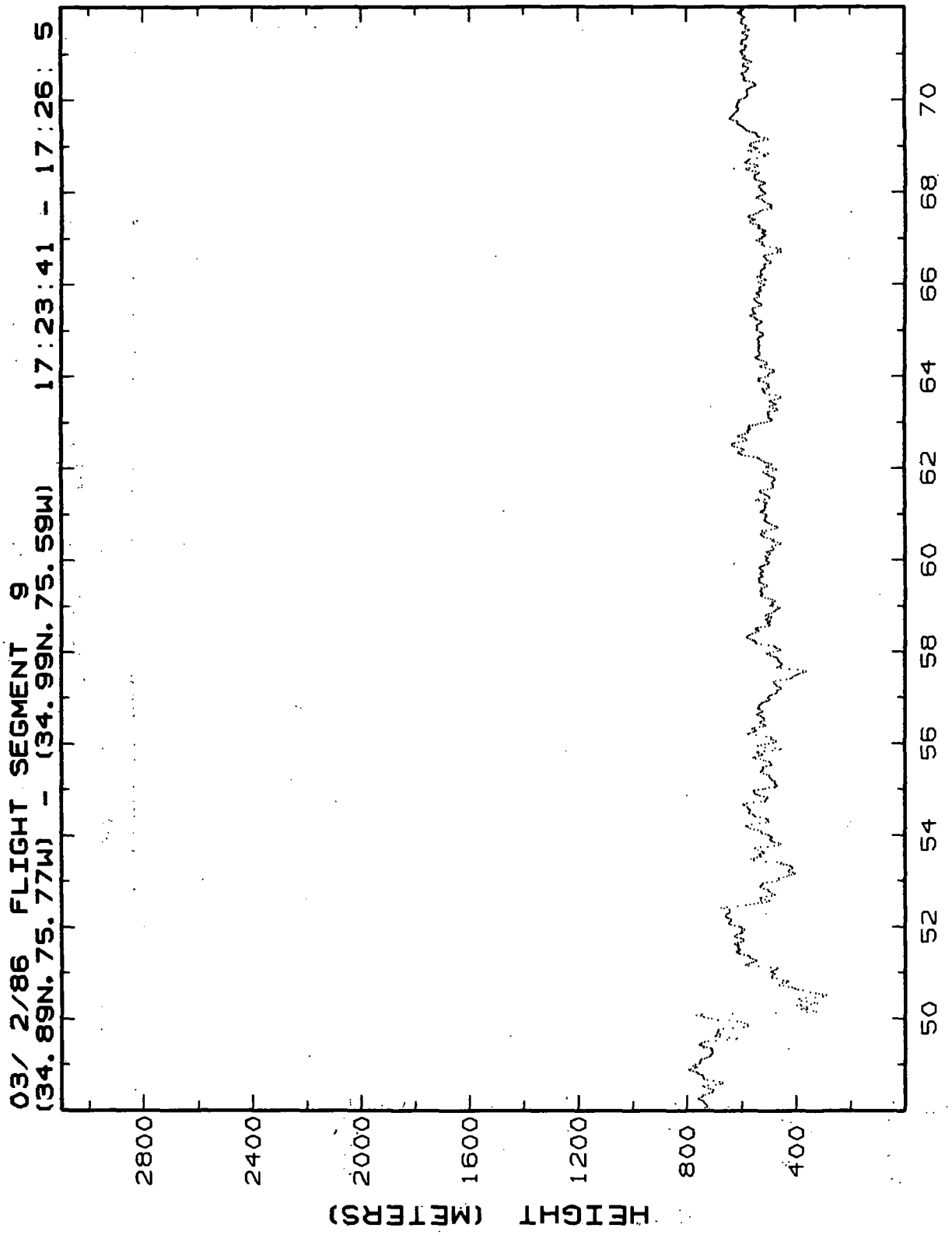

Figure 12.9c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 9, 48-72 km.

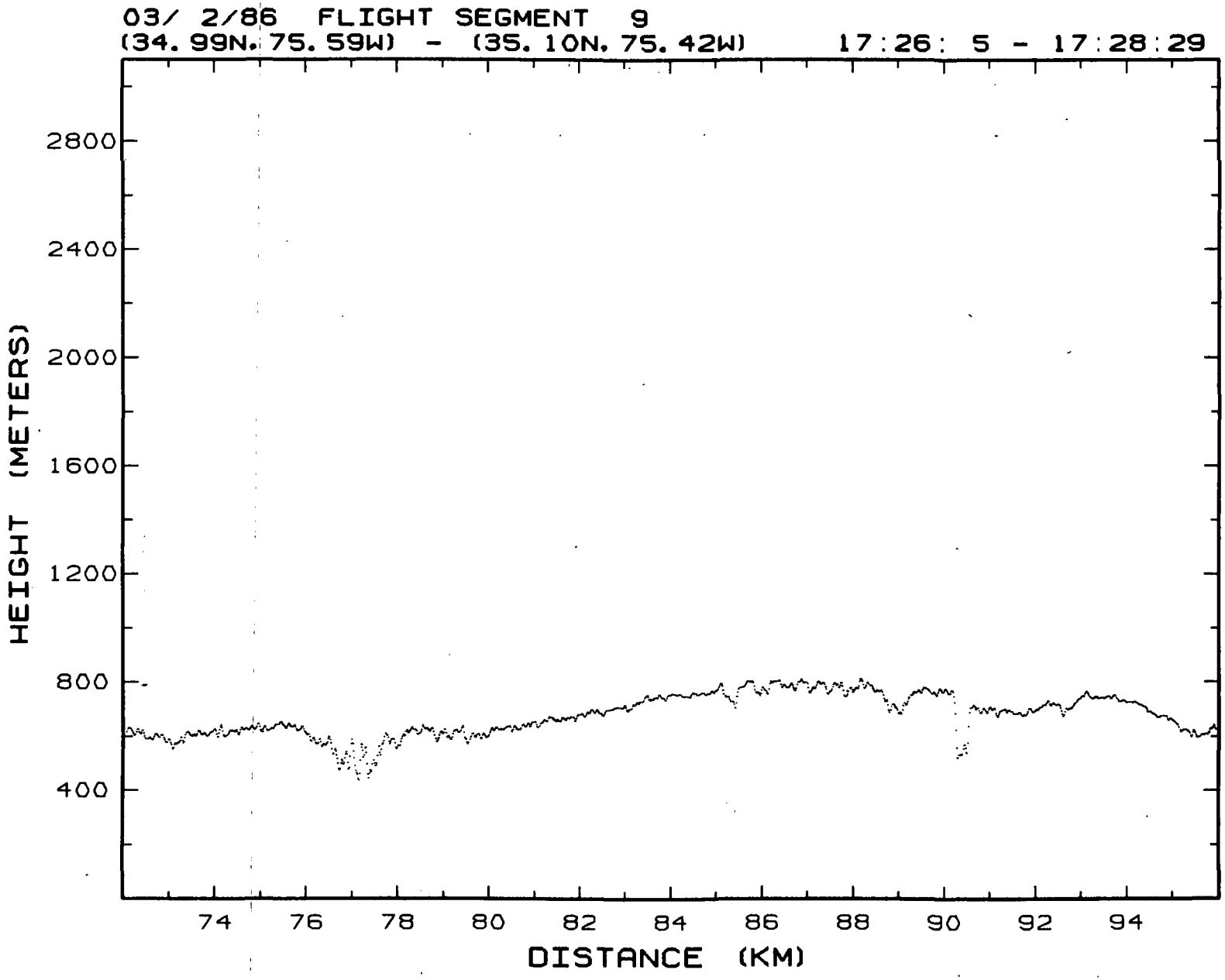

Figure 12.9d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 9, 72-96 km.

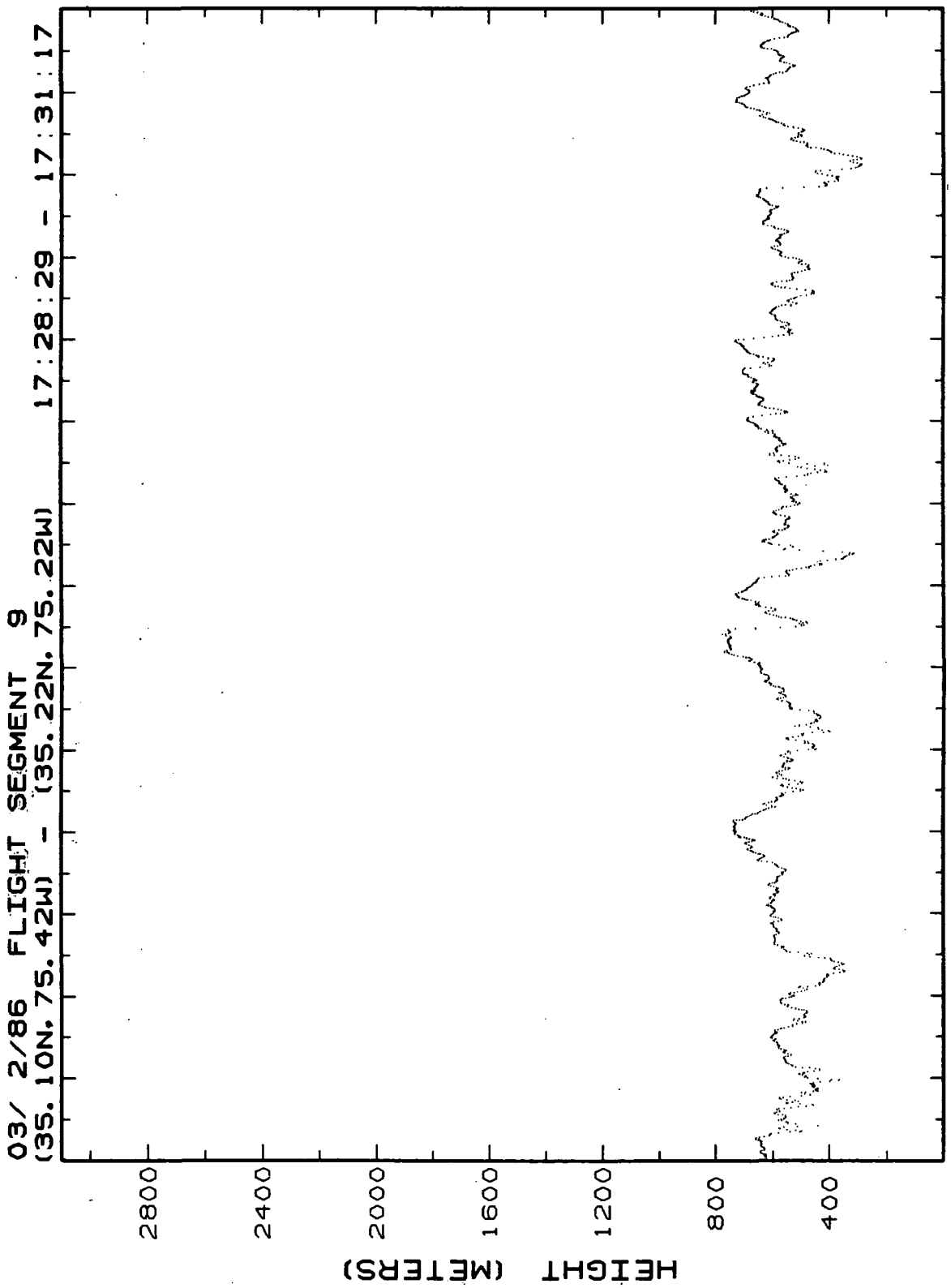

Figure 12.9e. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 9, 96-124 km.

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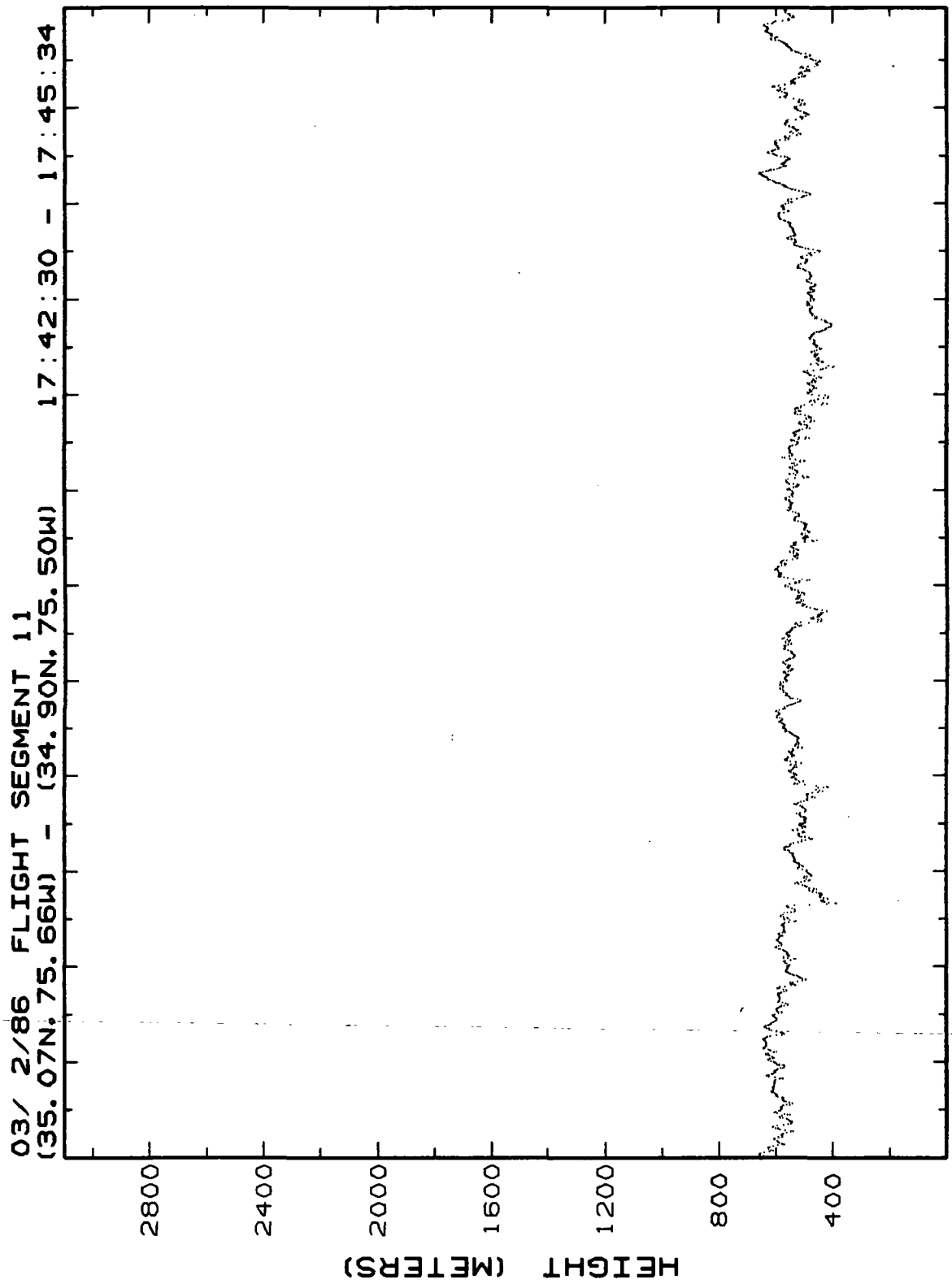

Figure 12.10a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 11, 0-24 km.

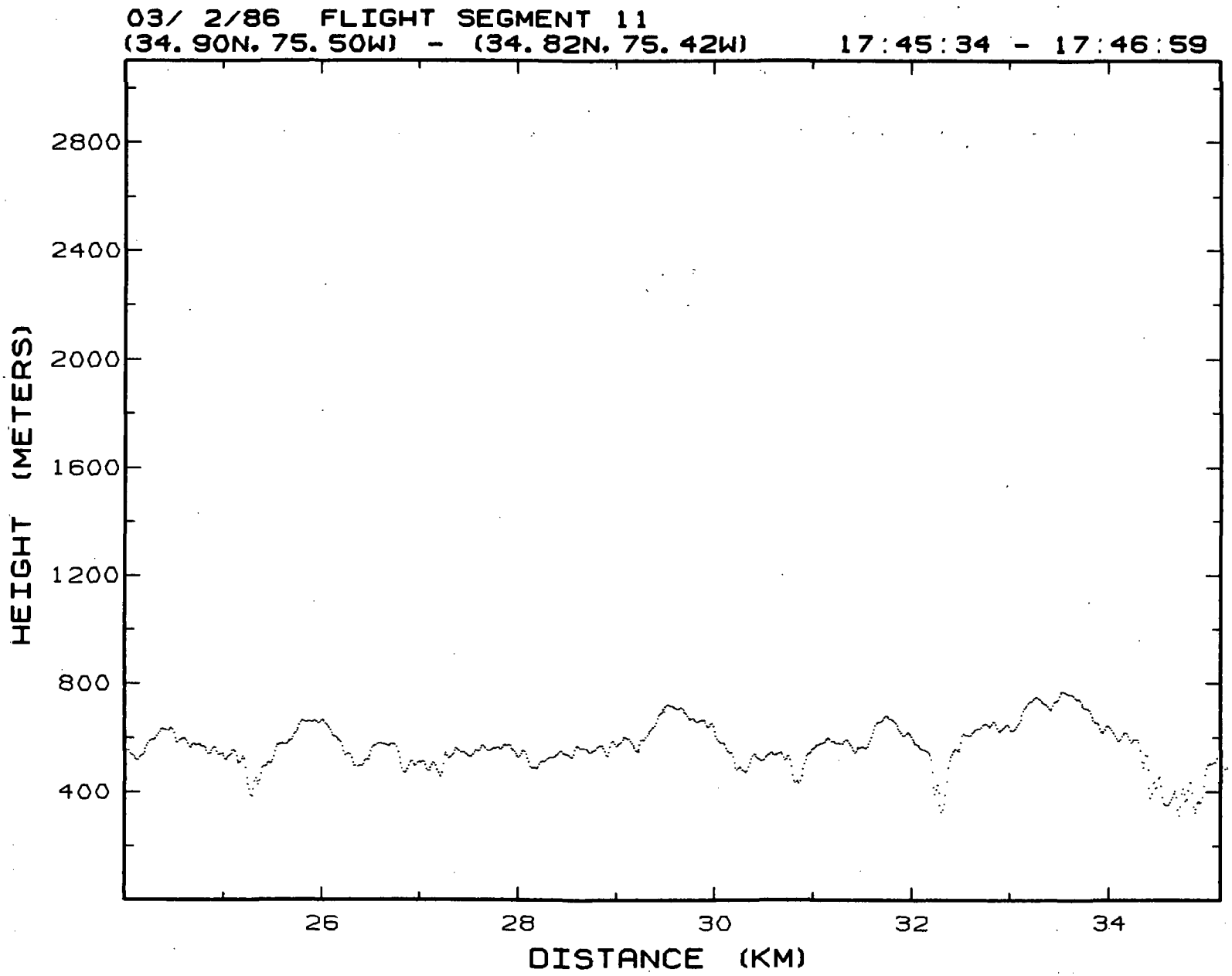

Figure 12.10b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 11, 24-35 km.

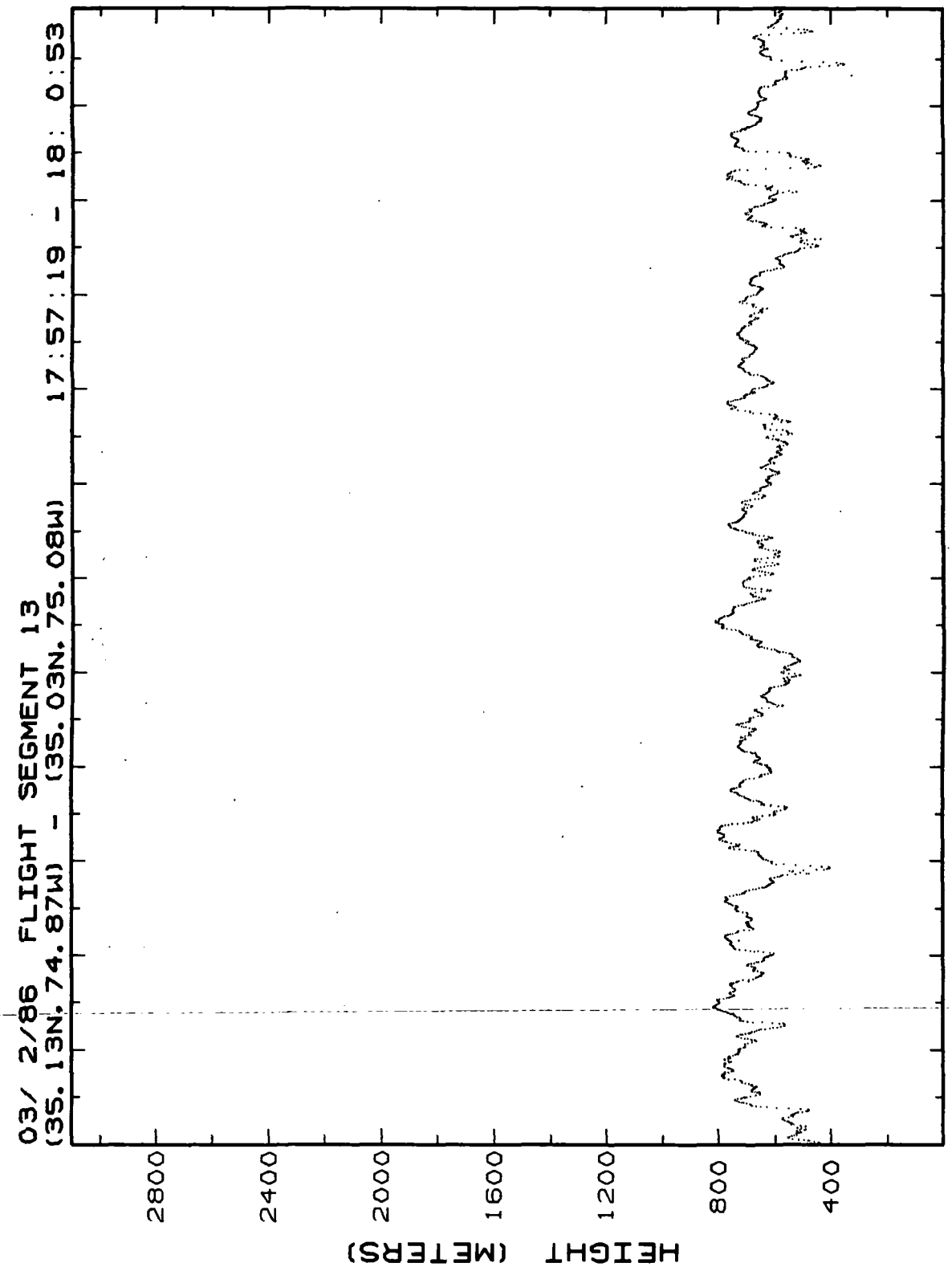

Figure 12.11a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 13, 0-24 km.

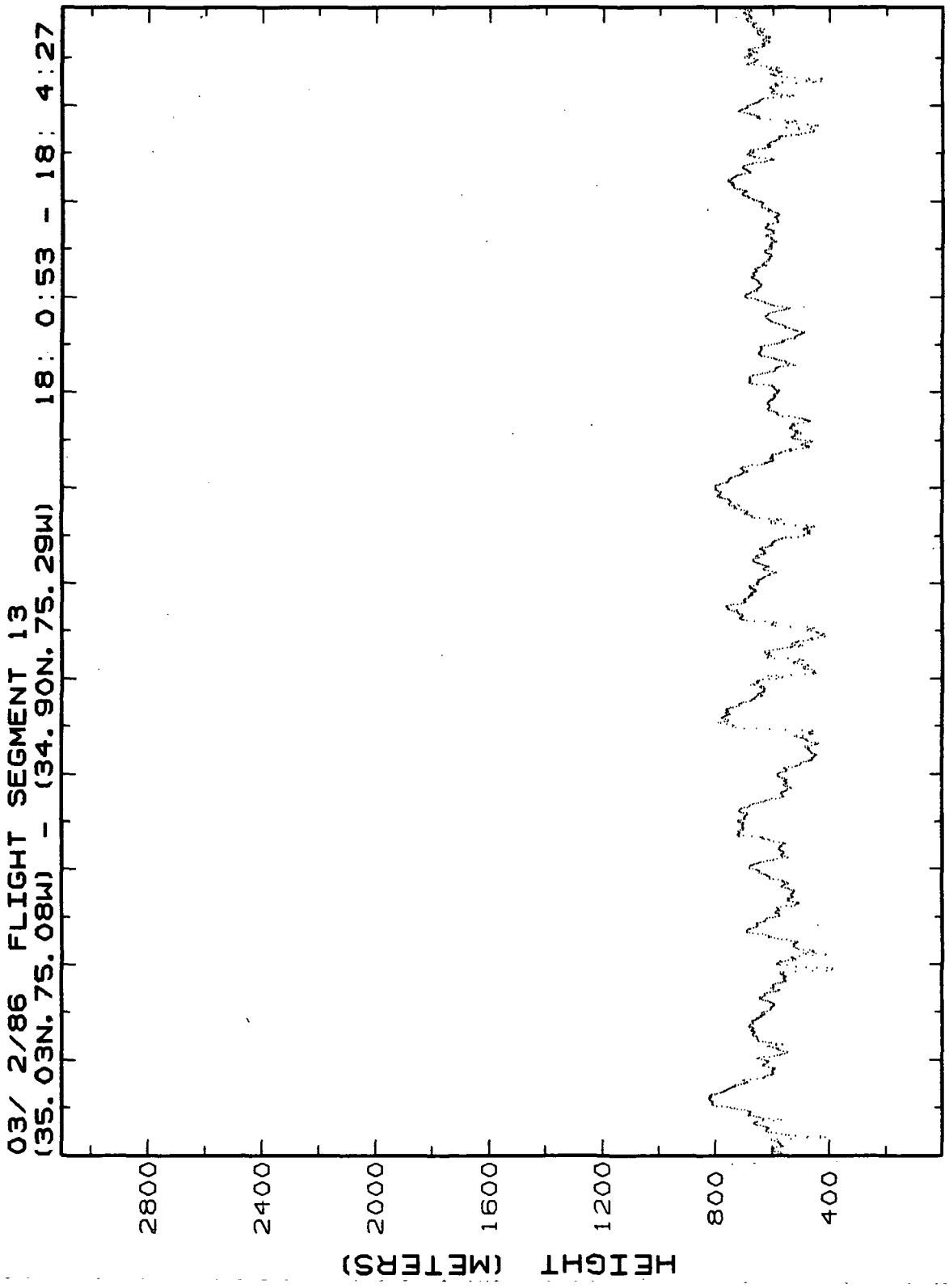

Figure 12.11b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 13, 24-48 km.

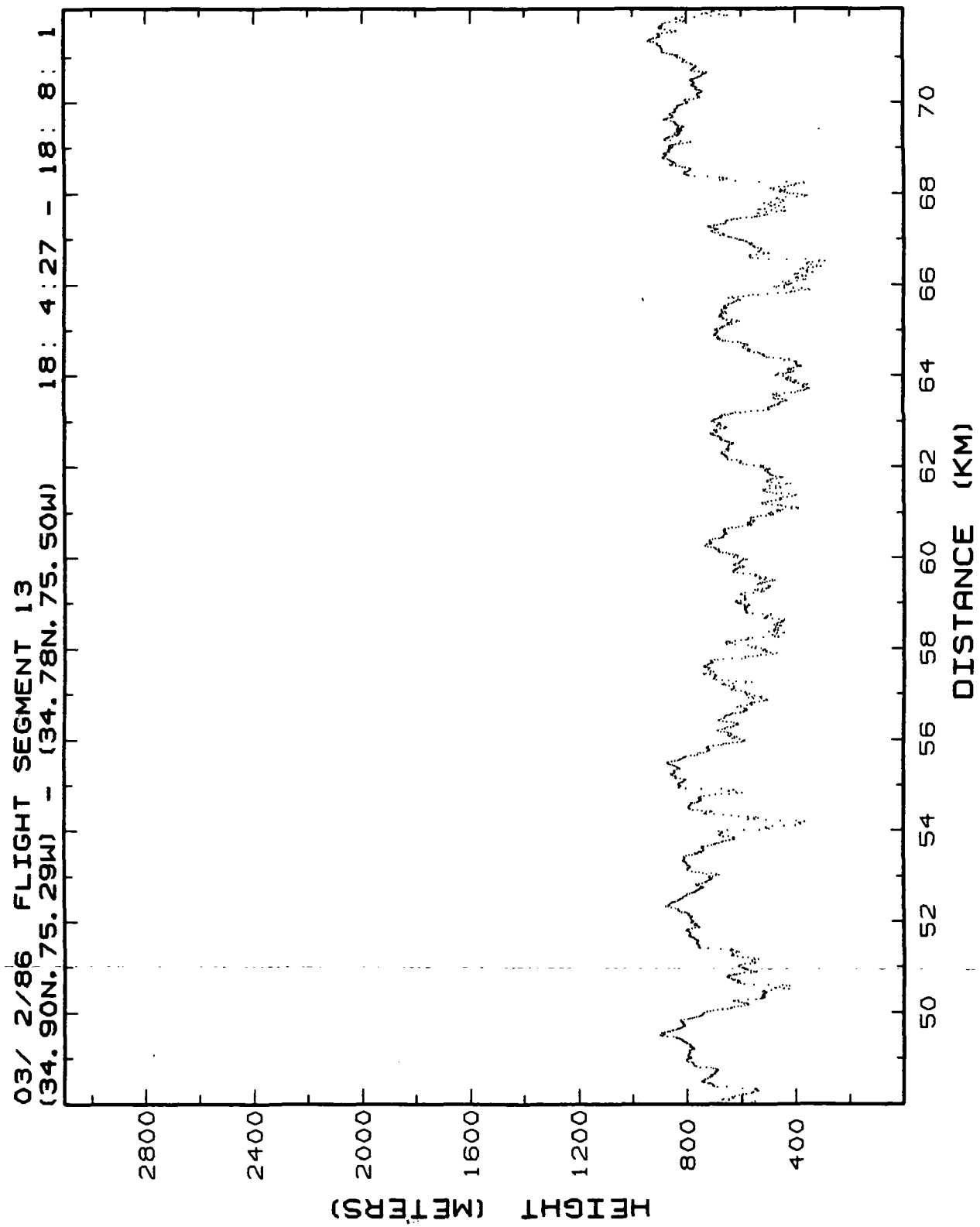

Figure 12.11c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 13, 48-72 km.

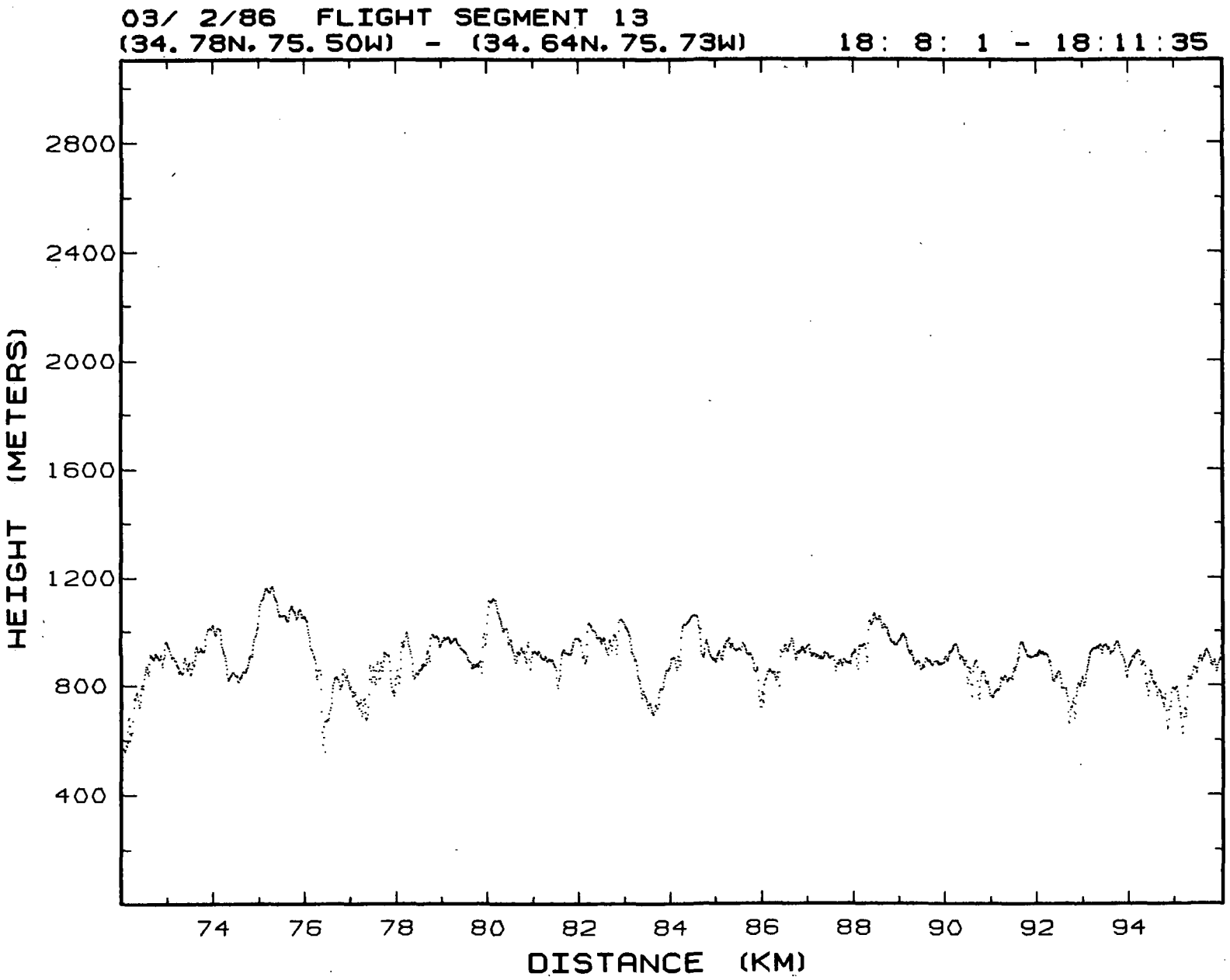

Figure 12.11d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 13, 72-96 km.

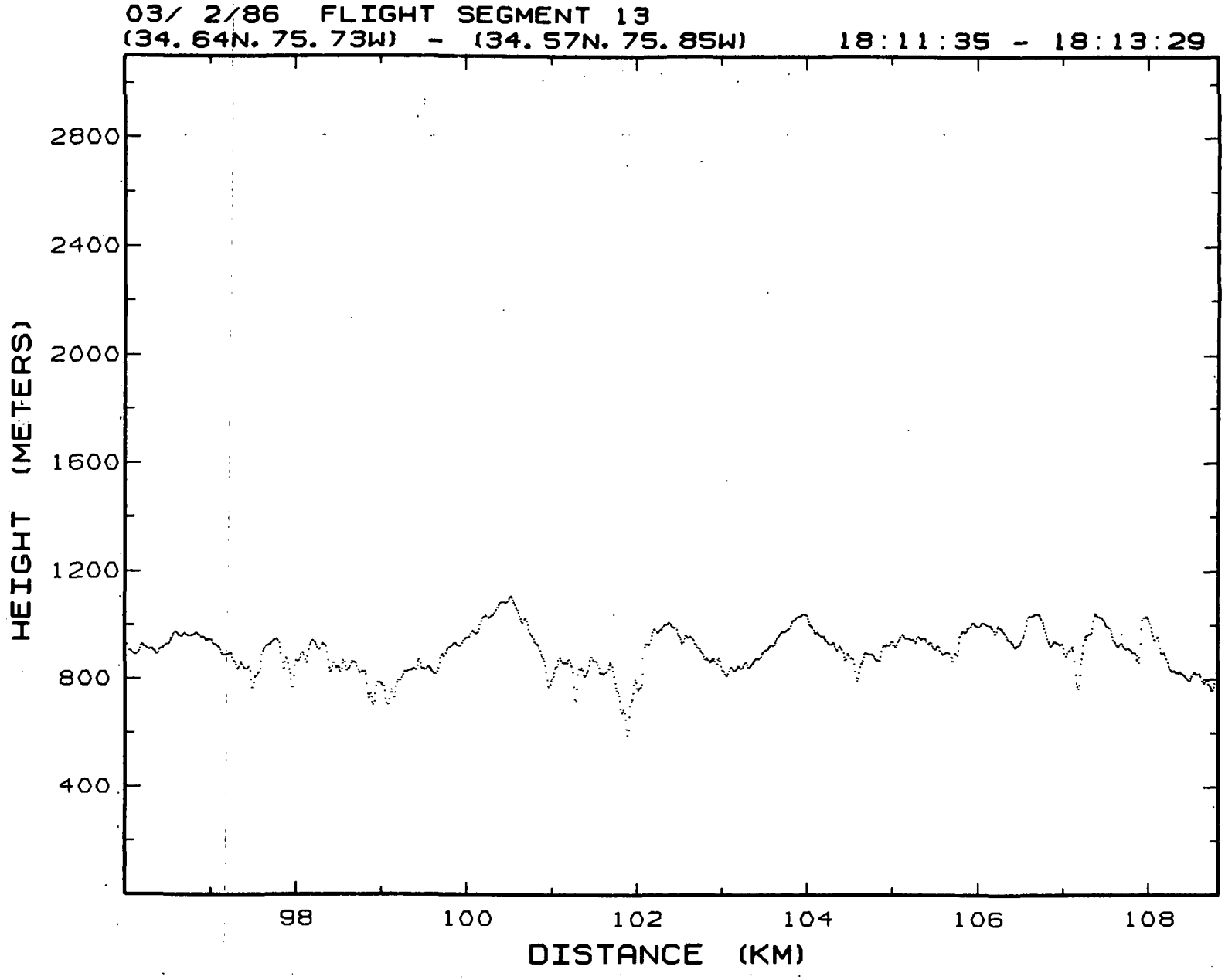

Figure 12.11e. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 13, 96-109 km.

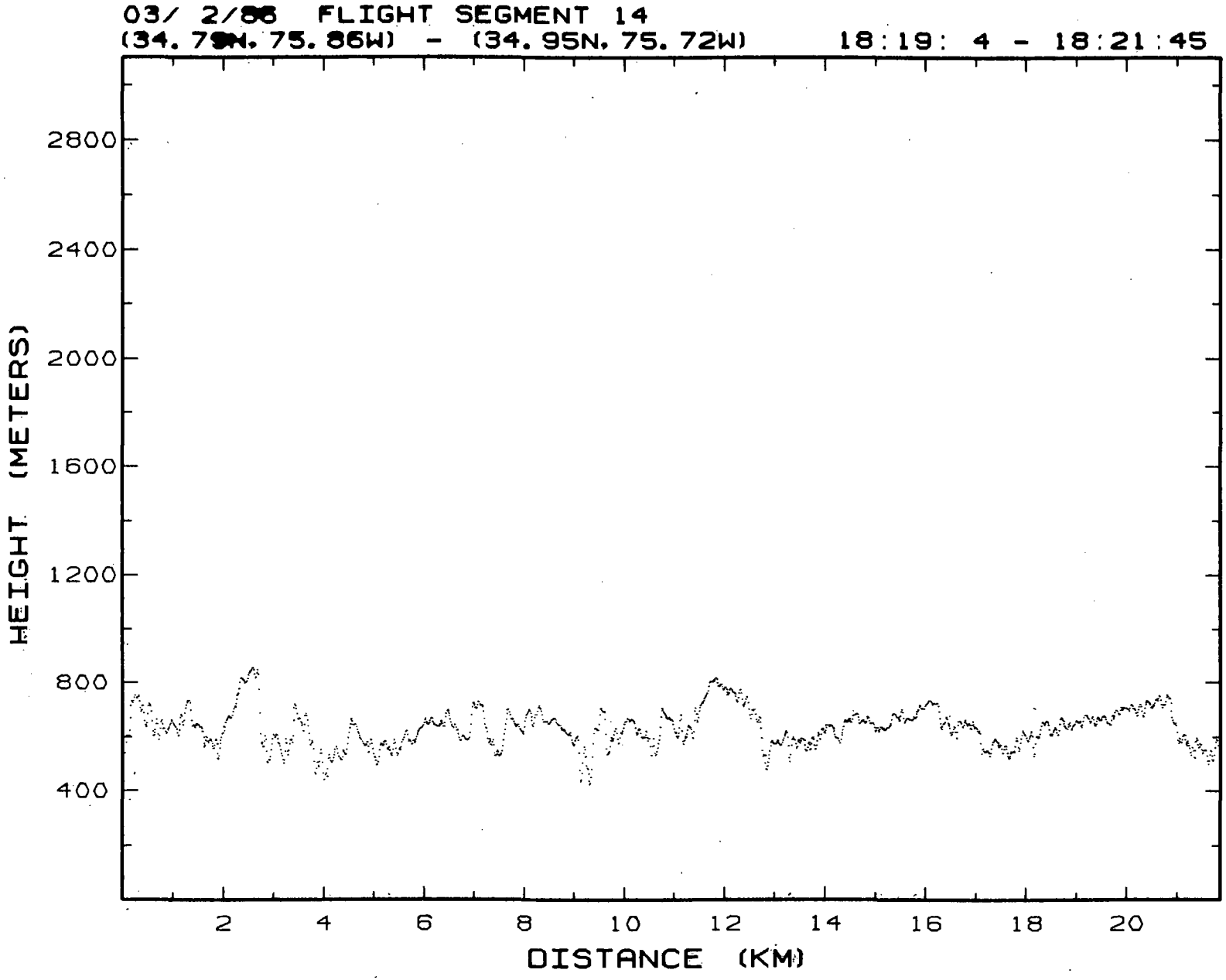

Figure 12.12a. Lidar retrieved MABL heights for Flight 2, 30-Jan-86, flight segment 14, 0-22 km.

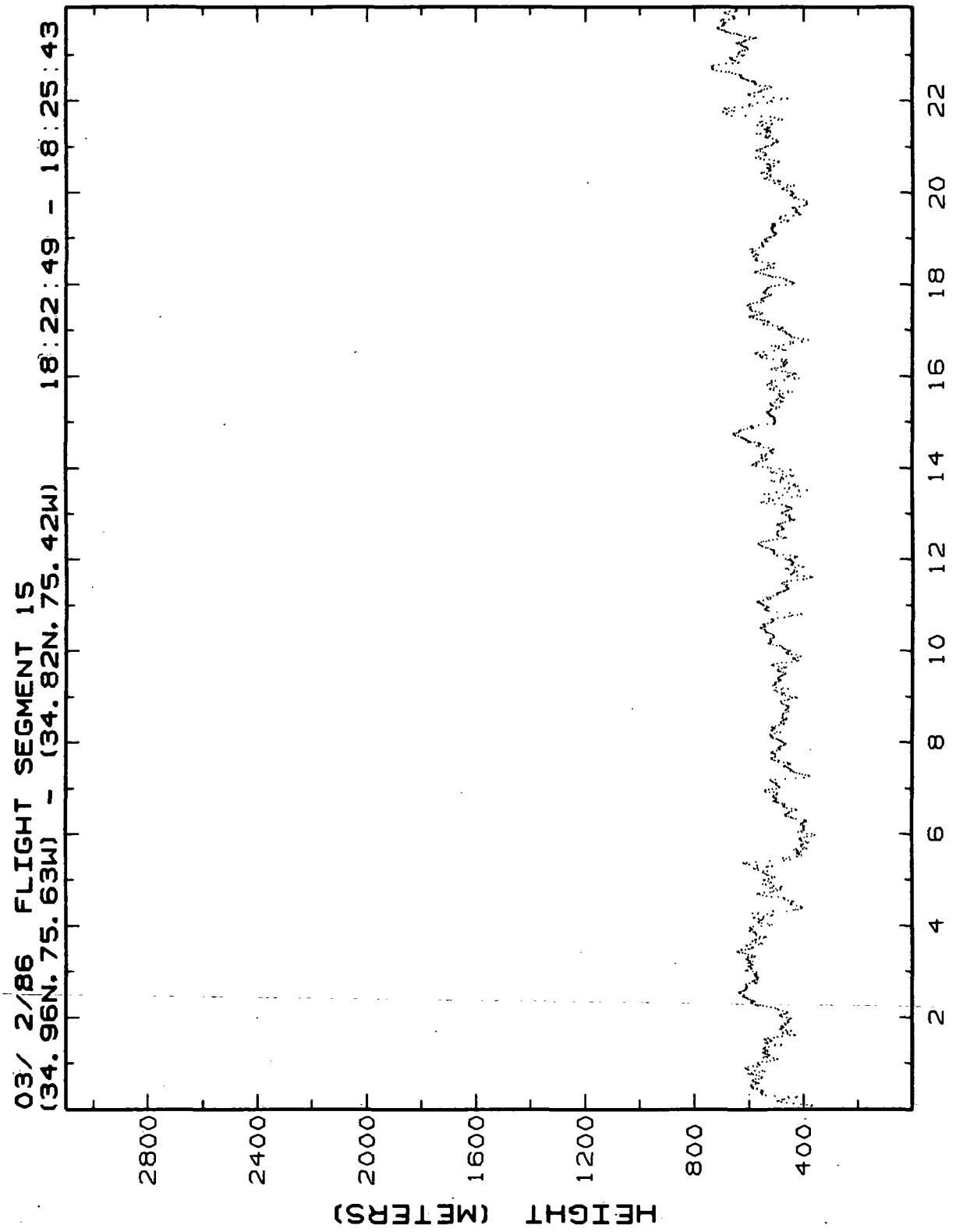

Figure 12.13a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 15, 0-24 km.

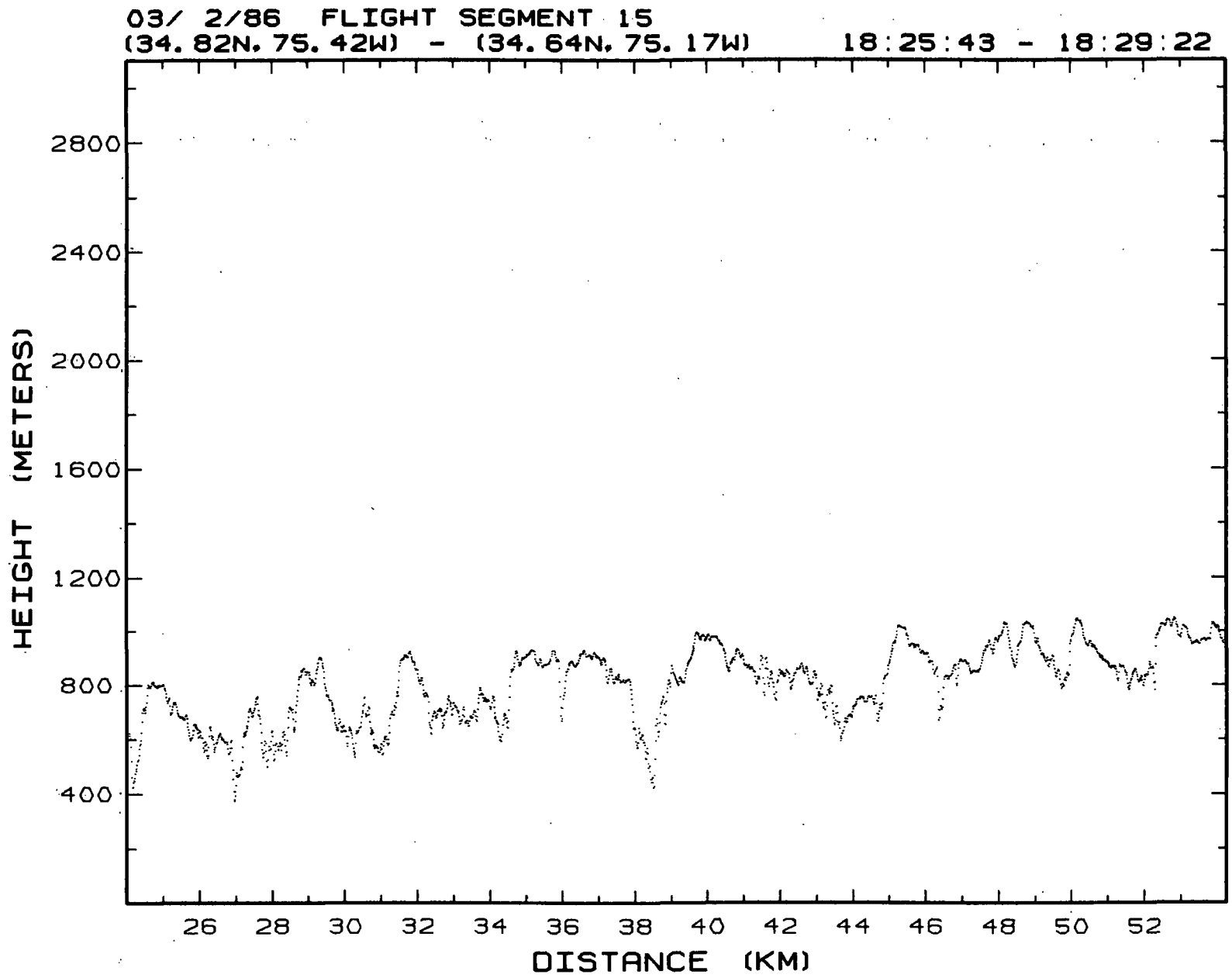

Figure 12.13b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 15, 24-54 km.

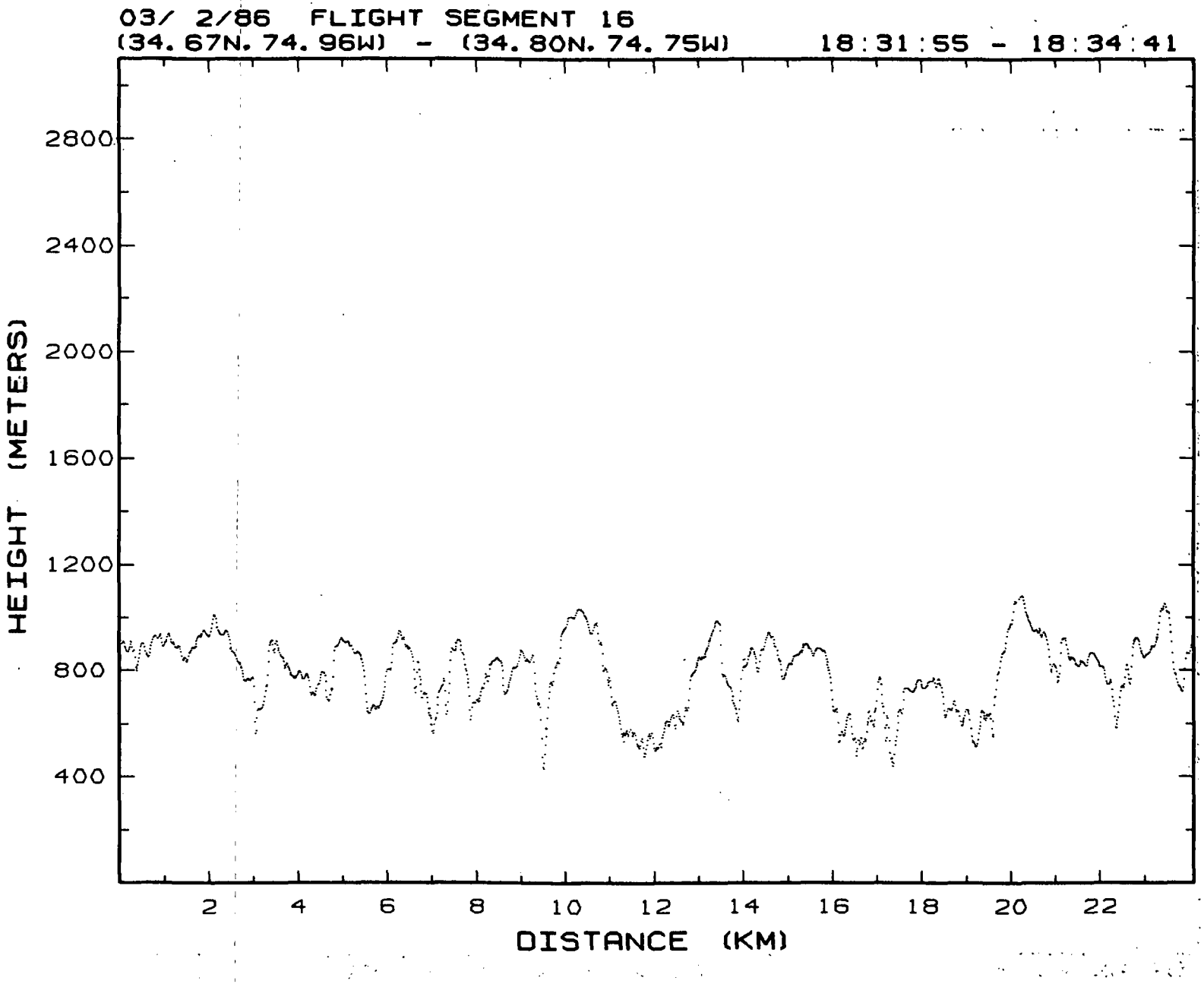

Figure 12.14a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 16, 0-24 km.

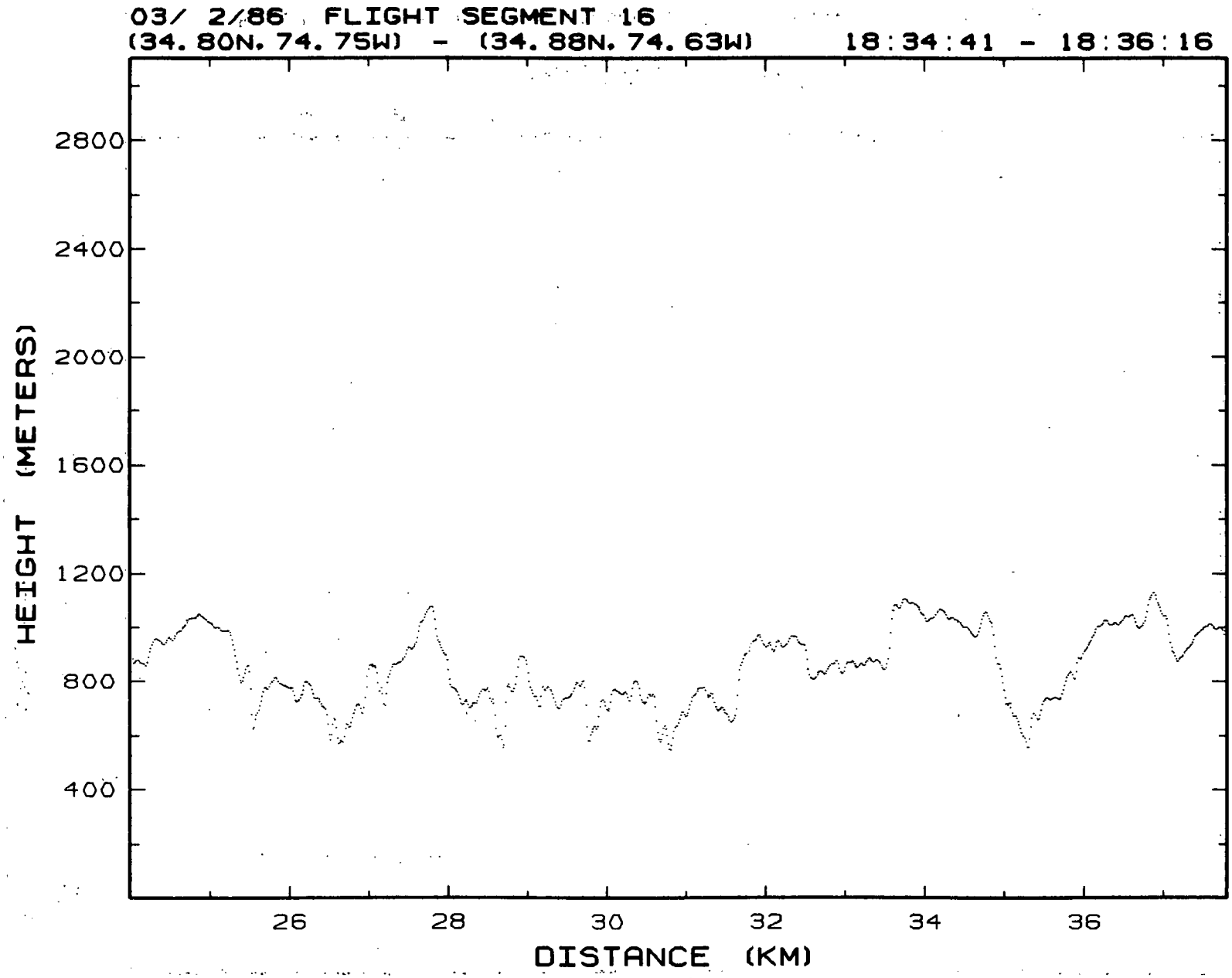

Figure 12.14b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 16, 24-38 km.

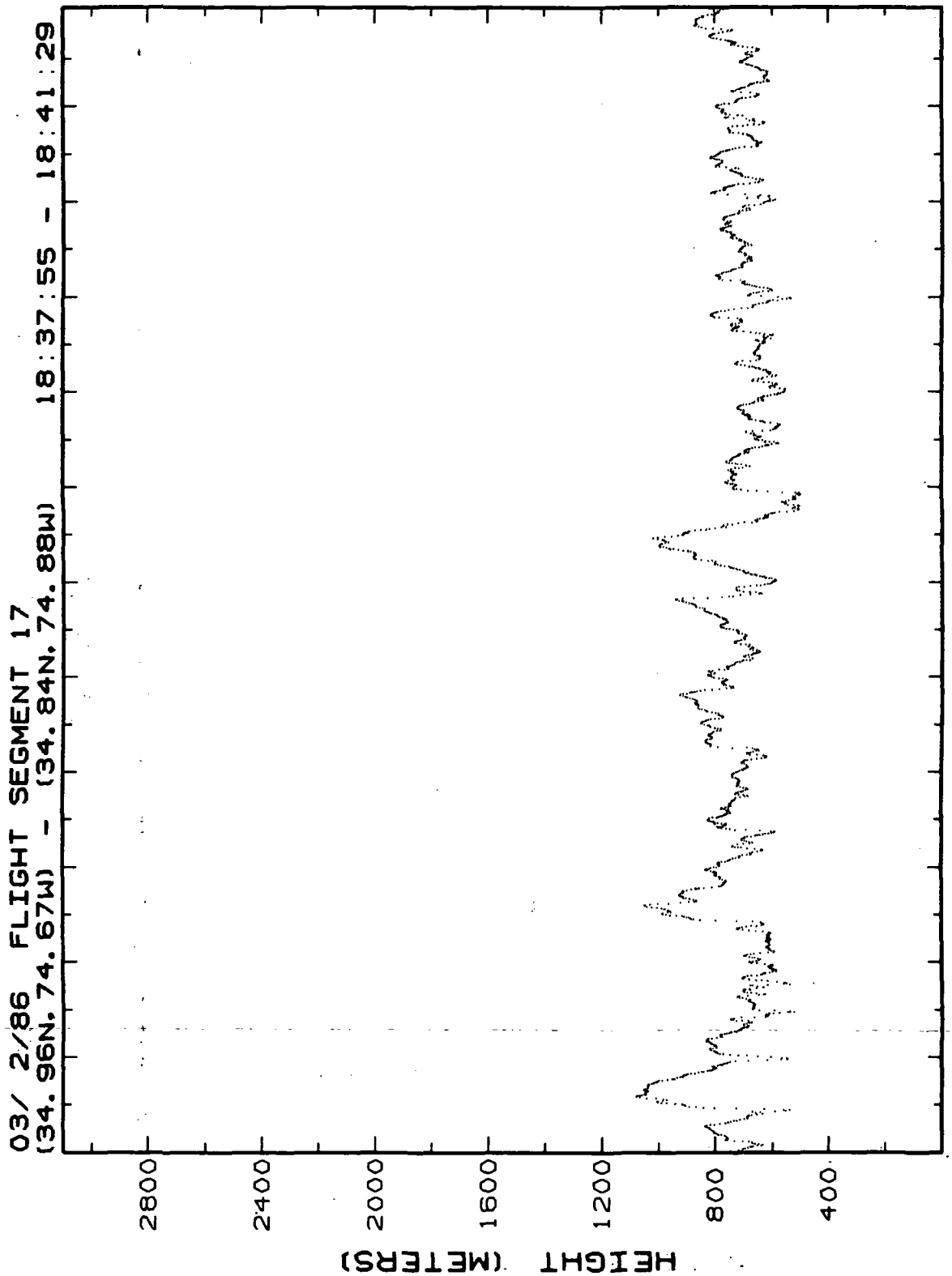

Figure 12.15a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 17, 0-24 km.

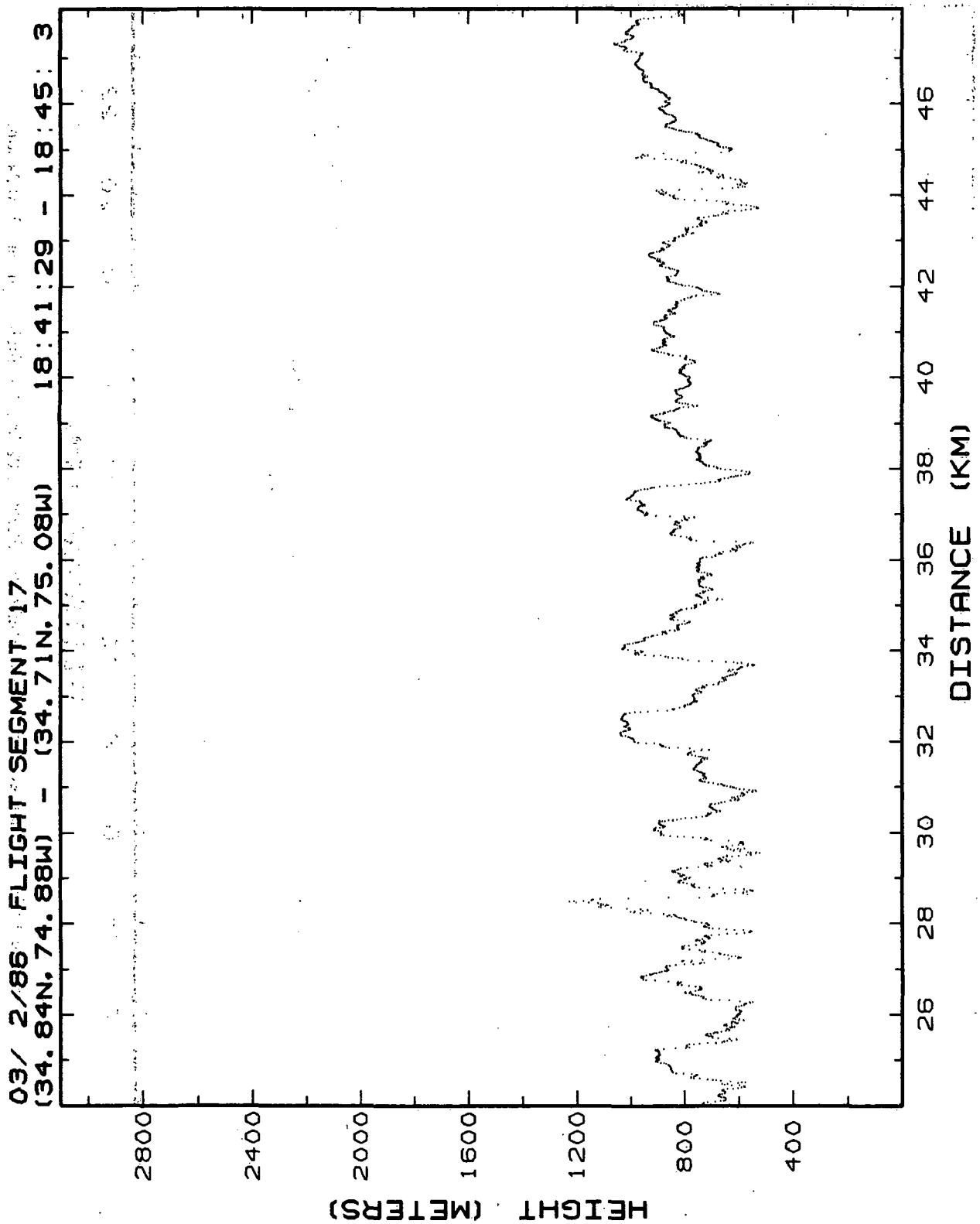

Figure 12.15b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 17, 24-48 km.

C-2

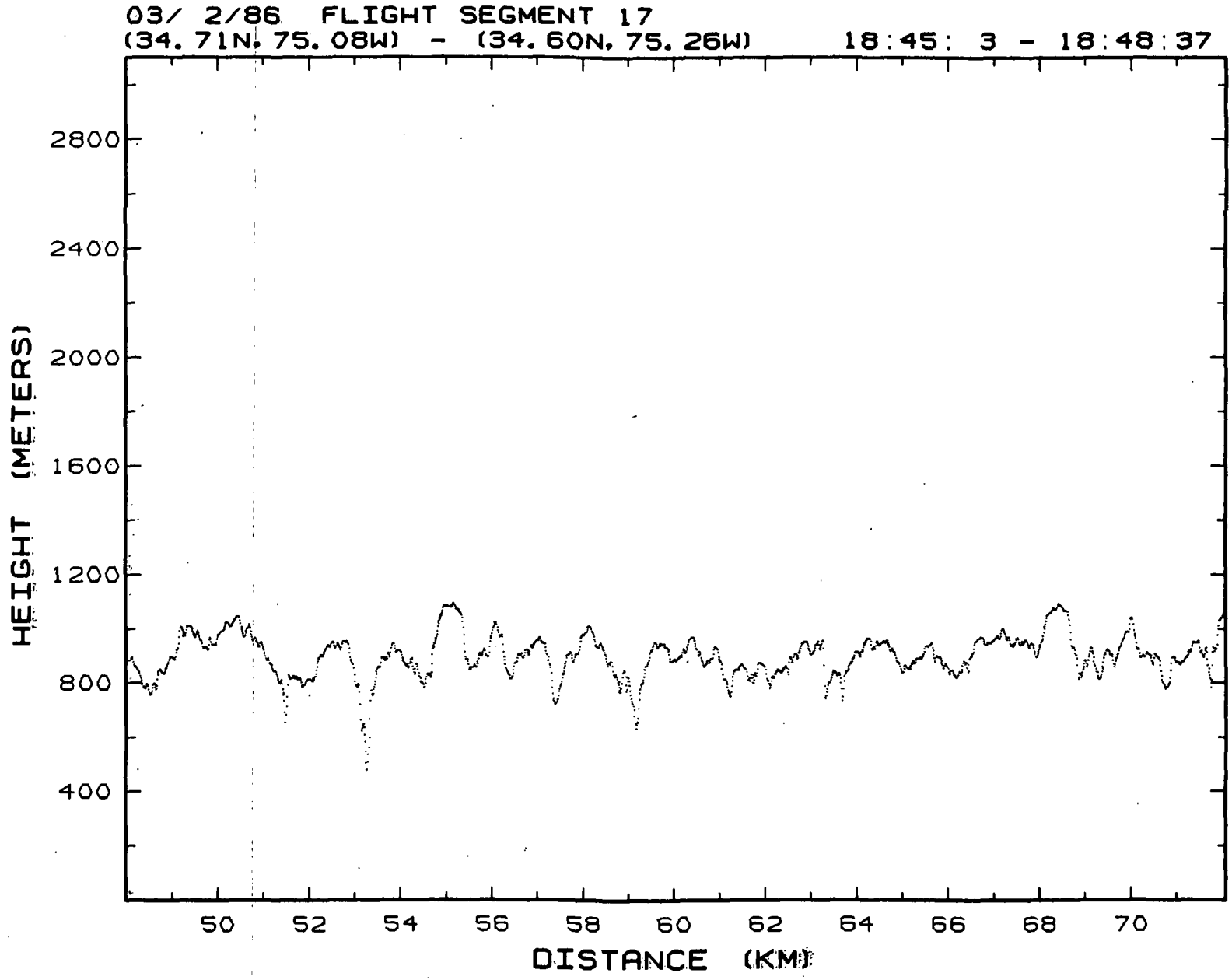

Figure 12.15c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 17, 48-72 km.

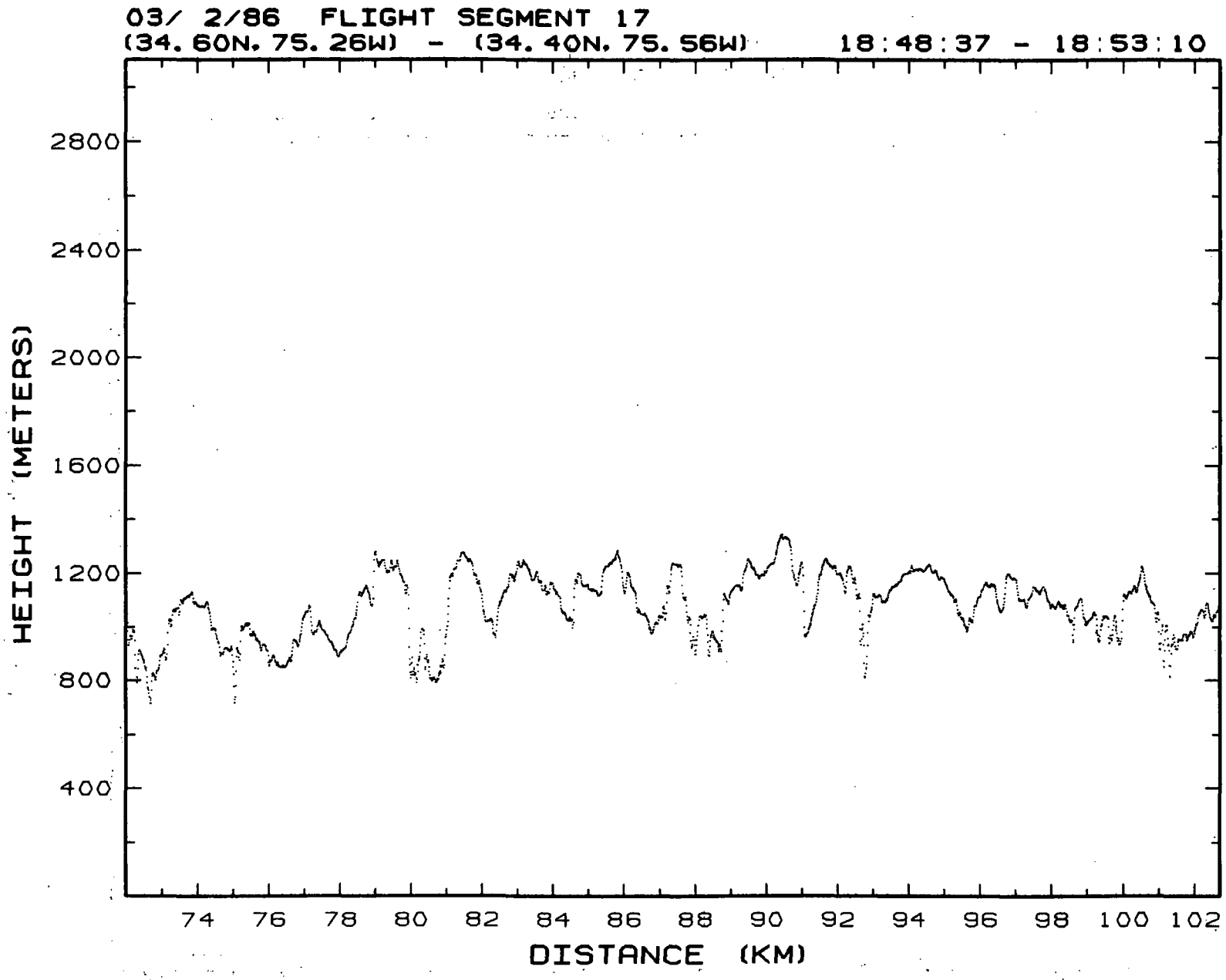

Figure 12.15d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 17, 72-102 km.

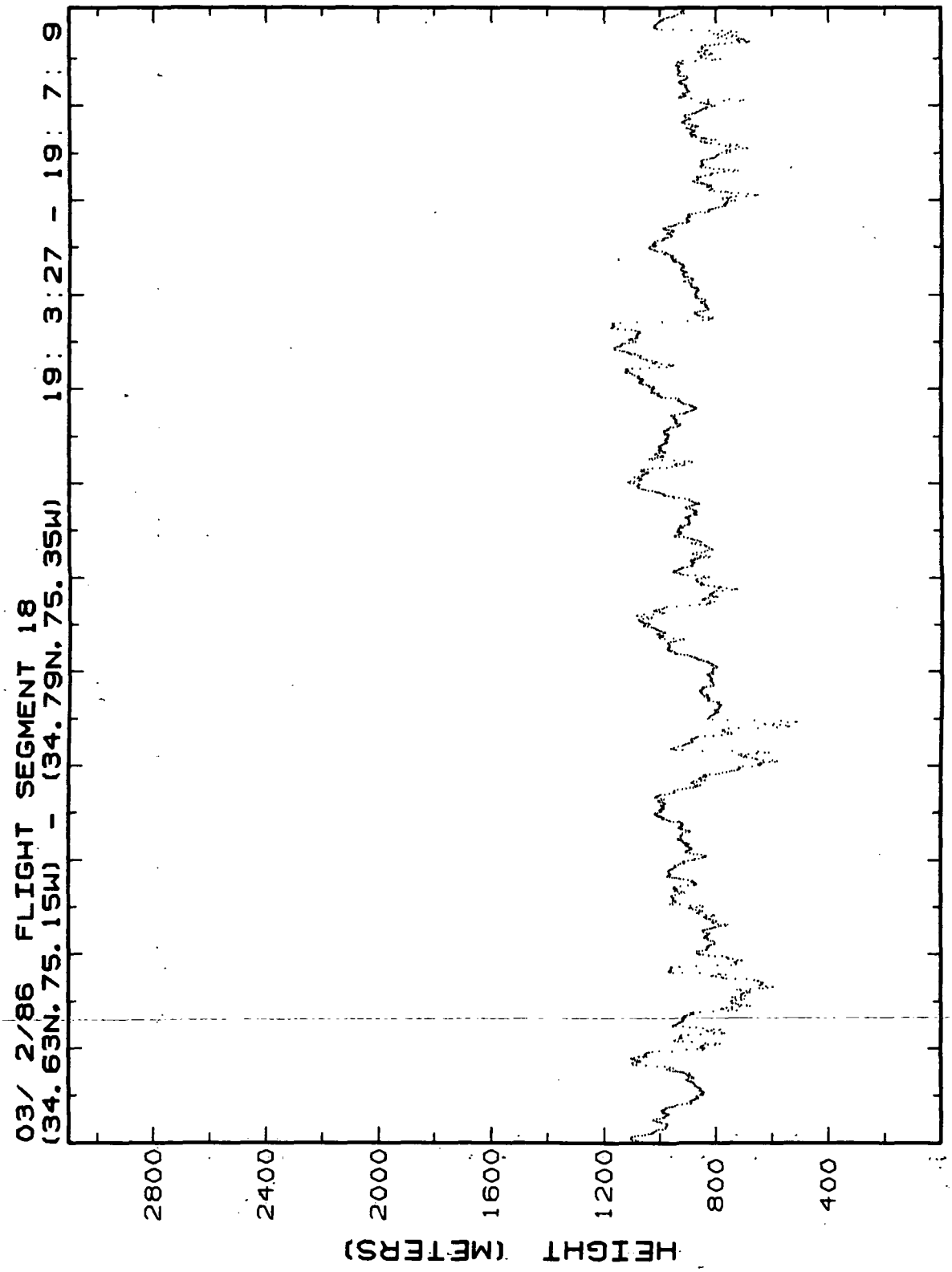

Figure 12.16a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 18, 0-24 km.

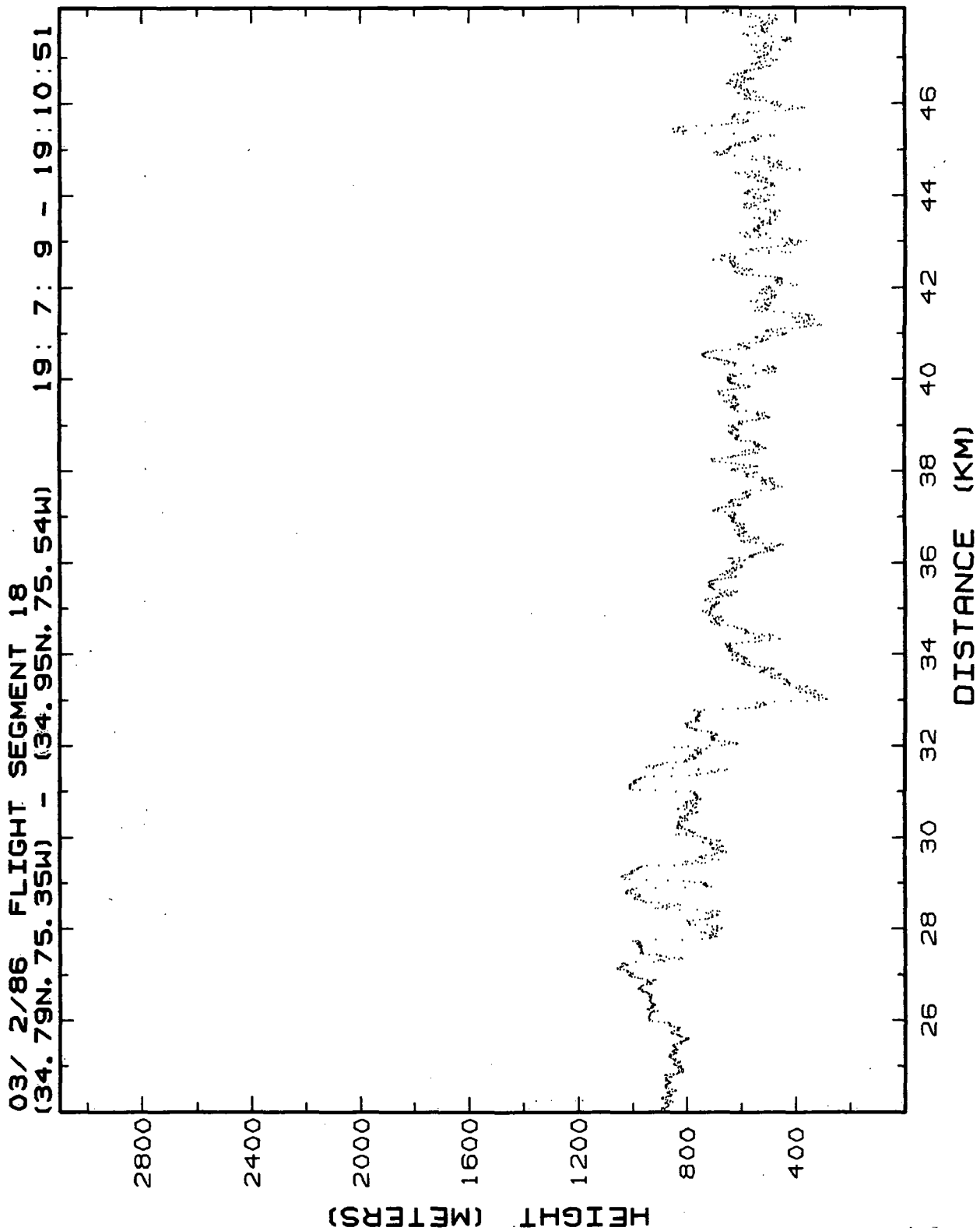

Figure 12.16b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 18, 24-48 km.

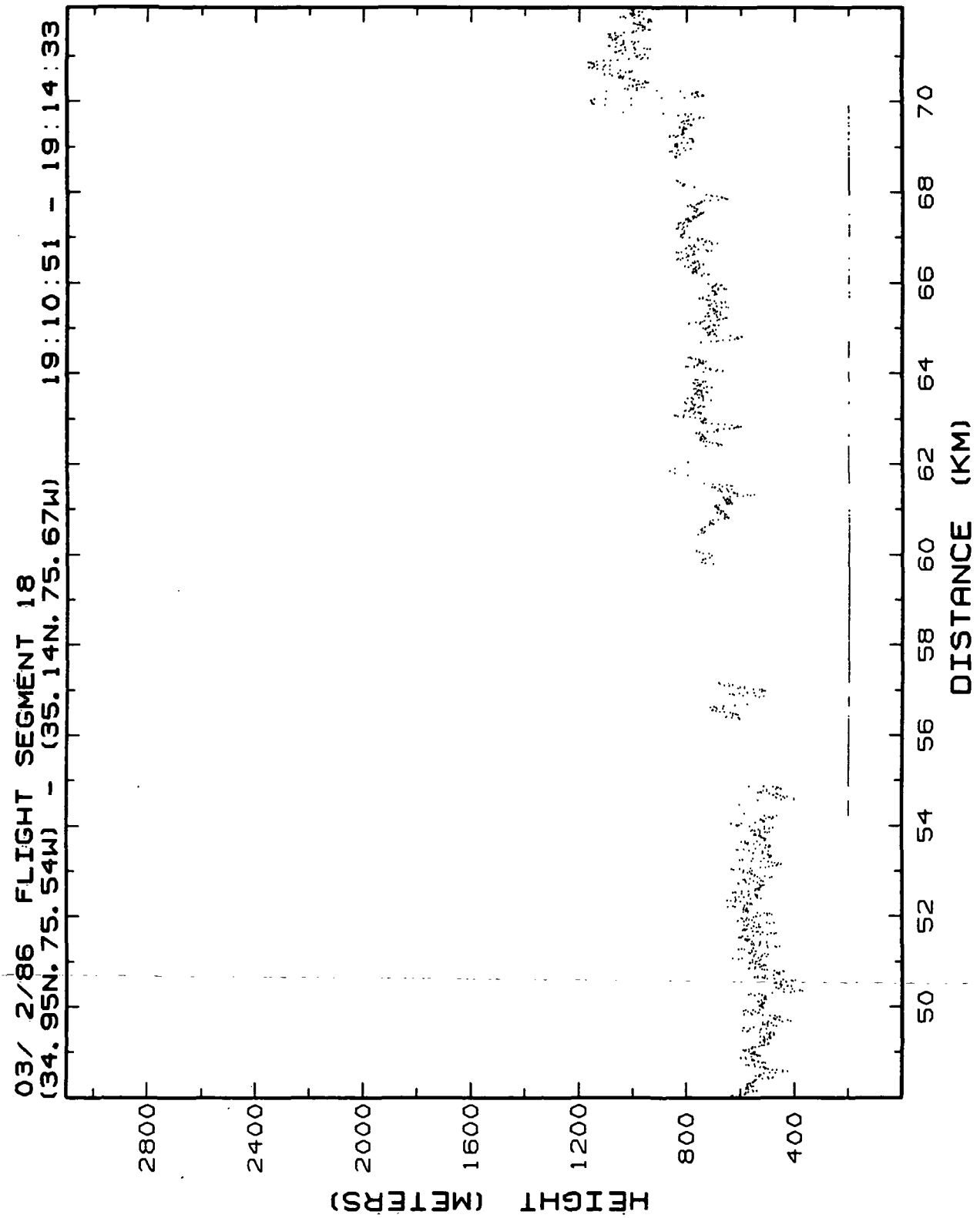

Figure 12.16c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 18, 48-72 km.

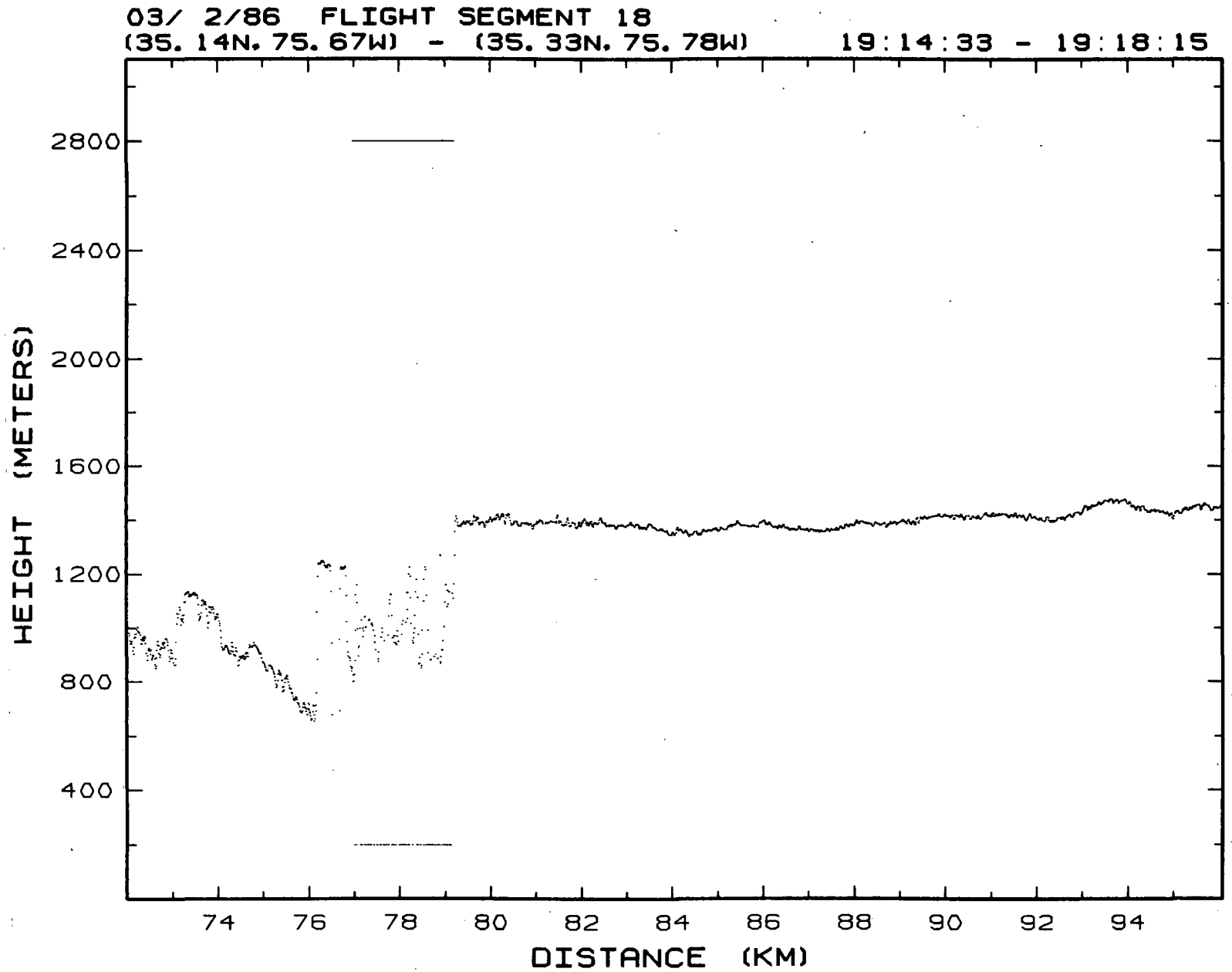

Figure 12.16d. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 18, 72-96 km.

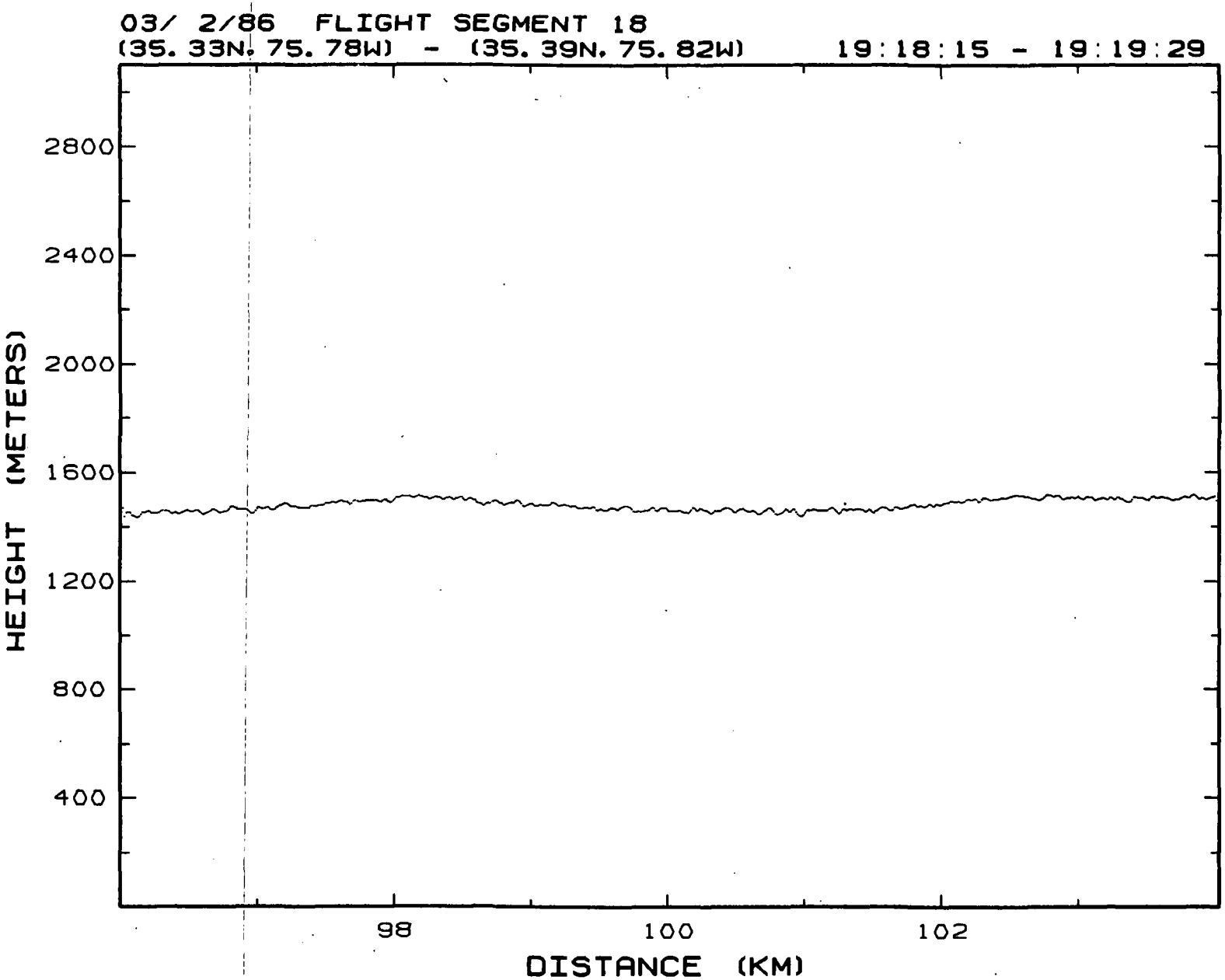

Figure 12.16e. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 18, 96-104 km.

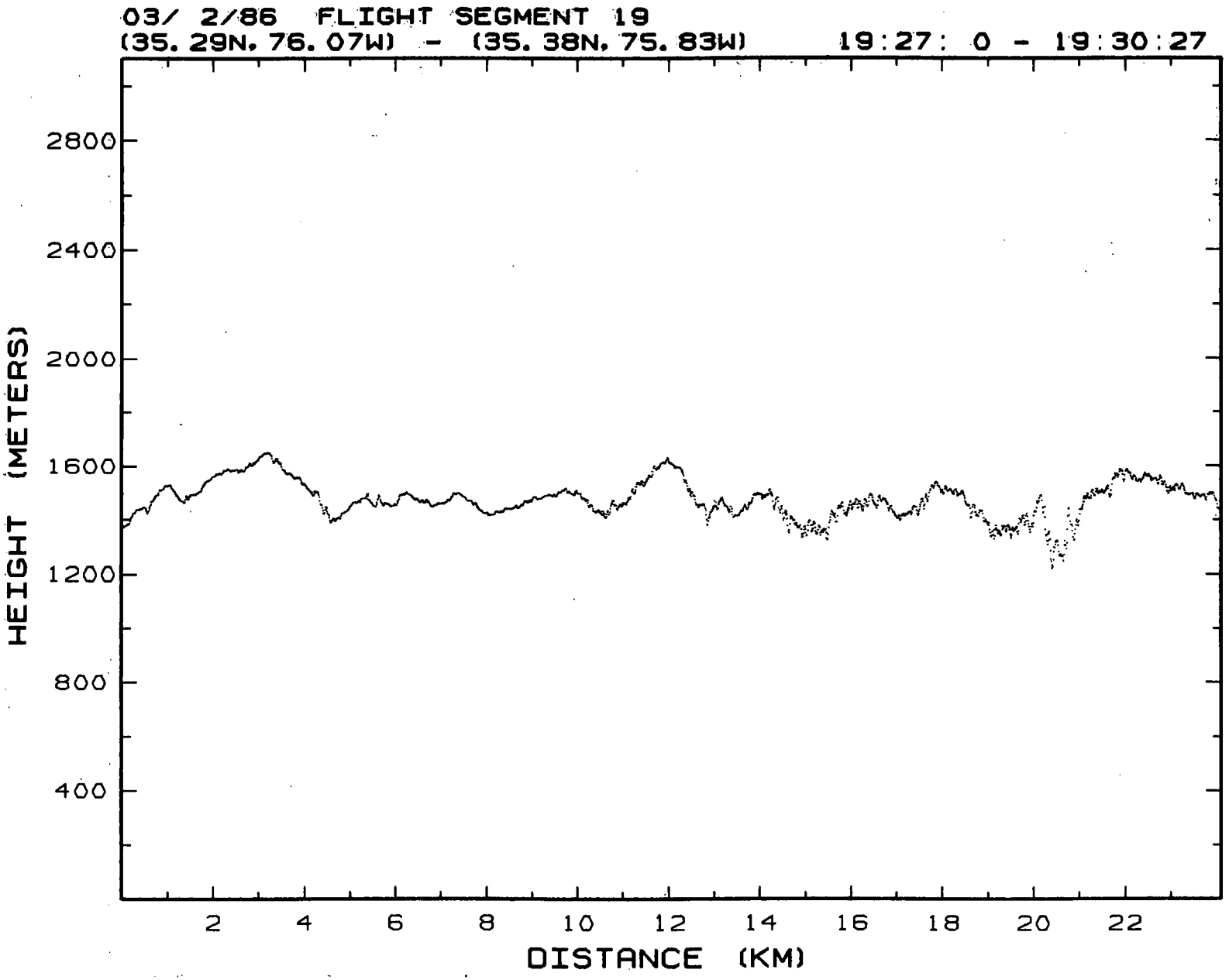

Figure 12.17a. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 19, 0-24 km.

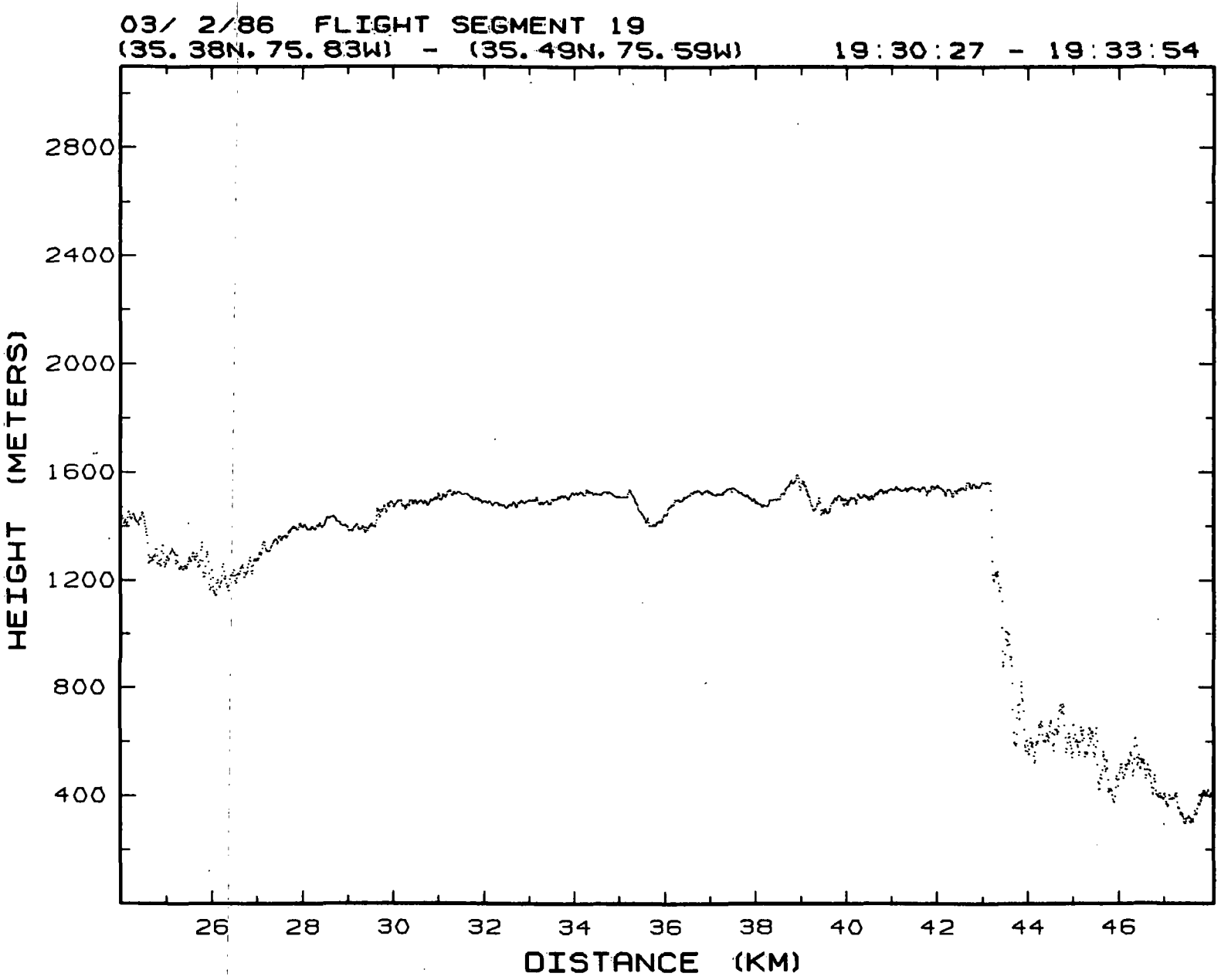

Figure 12.17b. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 19, 24-48 km.

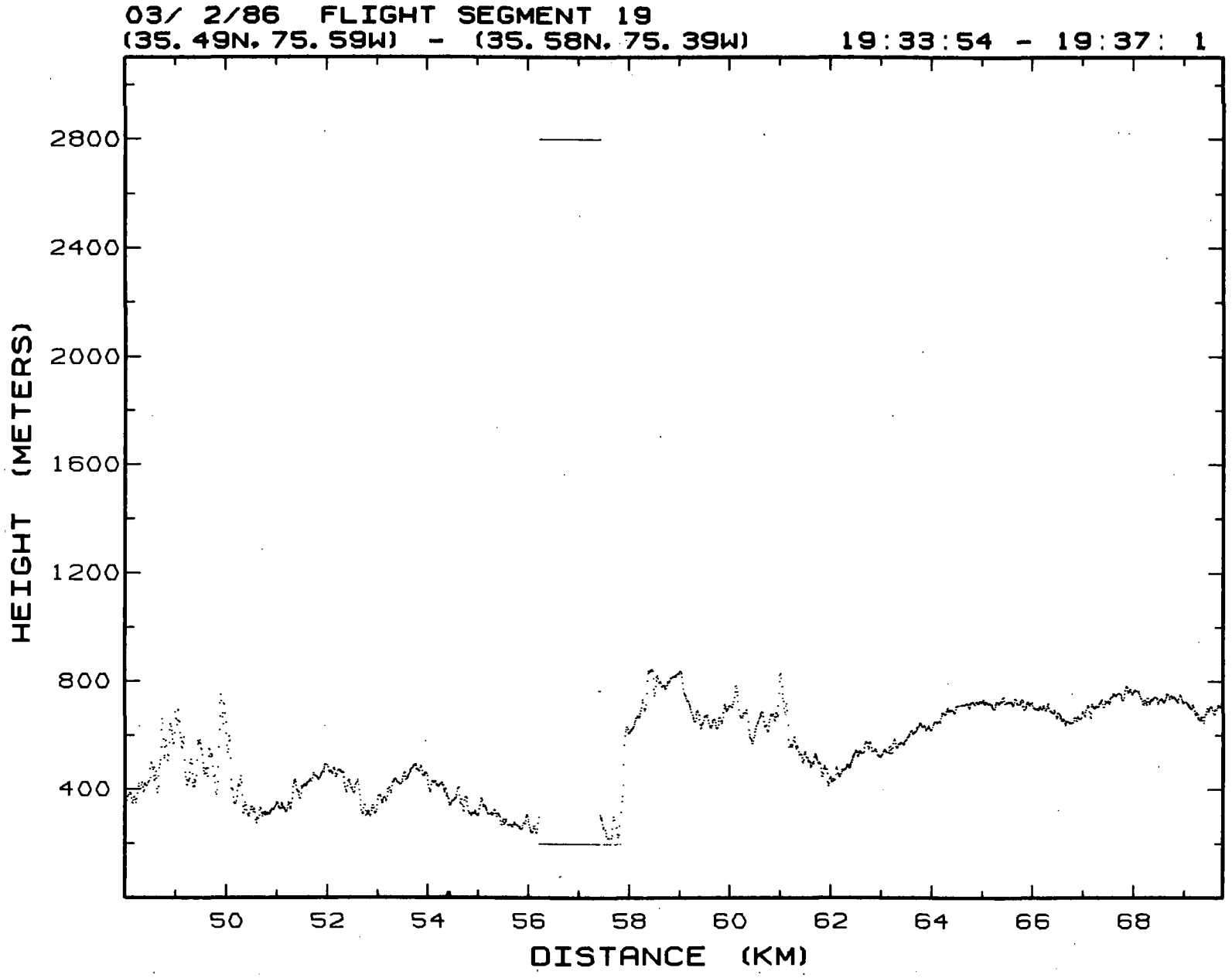

Figure 12.17c. Lidar retrieved MABL heights for Flight 4, 02-Mar-86, flight segment 19, 48-70 km.

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16. Abstract
The objective of this research project was to obtain high resolution measurements of the height of the Marine Atmospheric Boundary Layer (MABL) during cold air outbreaks using an Airborne Lidar System. The research was coordinated with other investigators participating in the Genesis of Atlantic Lows Experiment (GALE). An objective, computerized scheme was developed to obtain the Boundary Layer Height from the Lidar Data. The Algorithm was used on each of the four flight days producing a high resolution data set of the MABL height over the GALE experiment area. Plots of the retrieved MABL height as well as tabular data summaries are presented.

ATMOSPHERIC BOUNDARY LAYER
MARINE METEOROLOGY
LOW PRESSURE
REMOTE SENSING
OPTICAL RADAR
AIR-WATER INTERACTIONS
COLD POINTS
MIXING HEIGHT
ALGORITHM
COMP. PROG.
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